2001

Army Research Laboratory

ANNUAL REPORT

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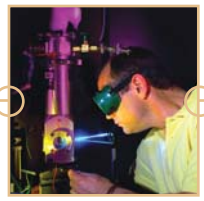

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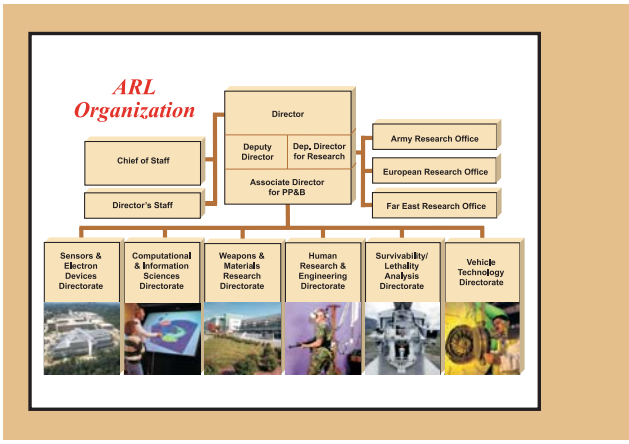
INTRODUCTION

The Army Research Laboratory (ARL) of the Army Materiel Command is the Army's corporate, or central, laboratory for materiel technology. Its diverse assortment of unique facilities and its workforce of government engineers and scientists comprise the largest source of world-class integrated research and analysis in the Army. ARL's programs consist of basic and applied research and survivability/lethality analysis.

ARL consists of six directorates, the Army Research Office, and the Chief of Staff's organization. Collectively these organizations execute research programs critical to Army Transformation.



Army Research Office (ARO) - scientific and far reaching technological discoveries in extramural organizations: educational institutions, nonprofit organizations, and private industry.

Computational and Information Sciences Directorate (CISD)- a broad spectrum of research focused on high bandwidth communication, advanced command and control techniques, battlefield visualization, weather decision aids, and defensive information operations. CISD operates one of four Department of Defense (DoD) Major Shared Resource Centers for high performance computing.

Human Research and Engineering Directorate (HRED) - scientific research and technology directed toward optimizing soldier performance and soldier-machine interactions to maximize battlefield effectiveness, and to ensure that soldier performance requirements are adequately considered in technology development and system design.

Sensors and Electron Devices Directorate (SEDD) - vertically integrated research and technology for developing advanced solid-state components and state-of-the-art sensor systems.

INTRODUCTION

Survivability and Lethality Analysis Directorate (SLAD) - integrated survivability and lethality analysis of Army systems and technologies across the full spectrum of battlefield threats and environments as well as analysis tools, techniques, and methodologies.

Vehicle Technology Directorate (VTD) - propulsion and structural engineering technologies for both air and ground vehicles in a leveraged partnership with NASA.

Weapons and Materials Research Directorate (WMRD) - material and weapons research to develop the technologies for future land combat systems.

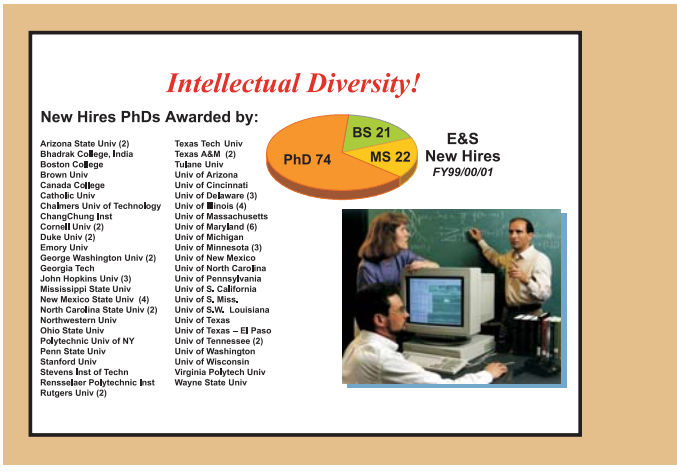
ARL has consistently provided the enabling technologies in many of the Army's most important weapons systems. Technology and analysis products are moved into Army Research, Development, and Engineering Centers (RDECs) and to other Army, DoD, government, and industry customers.

To gauge ARL capabilities and successes in accomplishing this mission, the status of the research workforce, the status of the technical infrastructure, the vitality of the funded research programs, and the annual scientific achievements of the organization are constantly reviewed and examined. This ARL Fiscal Year 2001 (FY2001) Annual Report provides an overview of ARL's status at the end of FY2001.

STATUS OF THE WORKFORCE

Our workforce numbered 2,008 in FY2001. These employees execute leading-edge research programs, operate and maintain world-class research facilities and equipment, and manage the myriad of administrative tasks incumbent to our research programs.

Of the 2,008 ARL team members, 1,218 are engineers or scientists. These talented engineers and scientists possess a very broad range of multi-disciplinary expertise. Engineering and scientific disciplines resident in the research workforce are: physicists, physical scientists, chemists, mathematicians, statisticians, metallurgists, computer scientists, aerospace engineers, electrical engineers, electronics engineers, mechanical engineers, general engineers, industrial engineers, materials engineers, engineering psychologists, chemical engineers, operations research analysts, meteorologists, and ceramic engineers.



The quality and expertise of the ARL workforce is unquestionably world class. However, ARL faces challenges today and in the future concerning its personnel. Current aging of the workforce and impending retirements over the next five years will cause a loss in our corporate knowledge base. At the same time, our requirements for highly technical personnel with advanced academic degrees are rapidly increasing. ARL is committed to continuing its innovative approach of managing its human resources without sacrificing quality in order to meet the Army's needs as effectively and efficiently as possible. Many personnel initiatives are already in place, some of these initiatives deserve recognition.

Our Science and Technology Academic Recognition System (STARS), a coupled fellowship program and recruitment initiative, has brought fine young minority scientists and engineers into the ARL team, and they are

already making their mark. STARS is a training and development program designed to assist exceptional and ambitious students from Historically Black Colleges and Universities (HBCU) and Minority Institutions (MI). Through STARS, we are growing our own diverse population of scientists and engineers with advanced degrees in research areas where there is a shortage projected for this century.

Thirty-two percent of ARL's engineer and scientist workforce hold doctoral degrees. Although this is a relatively high percentage, our goal is forty percent of our engineers and scientists with doctoral degrees. To reach that goal, we are aggressively recruiting and hiring research engineers and scientists with advanced degrees. Of the 45 new engineers and scientists hired in FY2001, 24 have doctoral degrees, 10 have master's degrees, and 11 have bachelor's degrees. This follows the trend over the past three years. One hundred and seventeen engineers and scientists have been hired since the beginning of 1999; of those, 74 have doctoral degrees, 22 have master's degrees, and 21 have bachelor's degrees. The 74 doctoral degrees were awarded by 49 academic institutes, reflecting our goal of obtaining the academic diversity requisite to sustaining an influx of new ideas and technical excellence.

In addition to recruiting employees with advanced degrees, ARL is actively promoting long-term academic education of our resident workforce. Eleven employees were engaged in full-time academic studies during FY2001. These education initiatives, coupled with our emphasis on training in leadership and management skills, and our ability to place employees in special assignments, will enable ARL to retain the capabilities required to provide the Army with the technologies required for Army Transformation.

STATUS OF THE TECHNICAL INFRASTRUCTURE

ARL is a geographically dispersed organization, operating unique research and development facilities and equipment at many locations. Our facilities are world class, but as is the case with any research organization, we must constantly review the status of our capital assets. In FY2001, we embarked on a capital investment program focused on providing ARL researchers with the scientific and experimental infrastructure vital for the development and transition of the technologies required for Army Transformation.

Most noteworthy of these investments is the upgrade of the cleanroom in the Zahl Physical Sciences Laboratory. The Zahl Physical Sciences Laboratory is a 372,000 Gross Square Feet (GSF) state-of-the-art research facility. The cornerstone of this building is the 10,000 Net Square Feet (NSF) Class 100 cleanroom. The facility also houses the Advanced Material Growth and Processing Facility, Display Materials Research Facility, and Advanced Microanalysis Facility in a portion of its 78,000 NSF general laboratory space. To meet current and future mission requirements, ARL is upgrading 4,900 NSF of the current cleanroom from Class 100 to 10, and adding 4,900 NSF of Class 10 space resulting in a Class 100/10 cleanroom of 14,900 NSF. The mission requirement for Class 10 laboratory space is driven by the need for fabrication of devices with very large defect-free areas and the building of three-dimensional circuits through full-size wafer bonding technologies. Extending 2D circuits in the 3rd dimension will increase the density and functionality and allow different materials systems to be integrated thereby enhancing functionality and performance. The Class 10 space will also provide the circuit designer an environment that will allow the merging of circuits and module concepts.

Other major upgrades initiated in FY2001 were:

- Active Stall Control Initiative
- Tactical Environment Simulation Facility
- Nanoscience Facilities
- Electro-Optical Experimental Equipment
- Atmospheric Boundary Layer Exploitation Facility
- Laser Optics Test Bed
- Molecular Characterization Facility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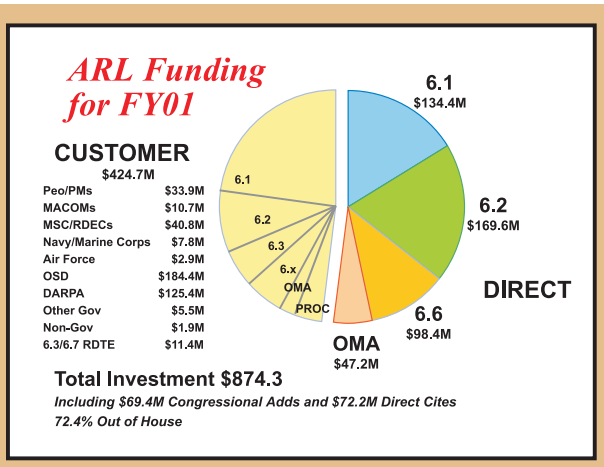
VITALITY OF THE RESEARCH PROGRAM

The ARL research program is robust, relevant, and structured to provide the scientific and technical underpinning requisite to achieving Army Transformation. Basic scientific investigations focus on critical areas in mathematical and computer sciences, chemistry, materials science, physics, life science, electronics, mechanical sciences, and environmental sciences. Applied technology efforts focus on solving Army Transformation challenges in survivability, lethality, C4I (command, control, communications, computers, and intelligence), sensors, sustainability, and the human dimension. Technologies are transitioned to the RDECs for inclusion in Army materiel systems. ARL also internally transitions technologies to support its missions in survivability/lethality analysis and MANPRINT/human factors analysis.



ARL total obligation authority for FY2001 was $874.3M, an increase of $105M from FY2000. FY2001 direct mission funding was $449.6M and customer reimbursable funding was $424.7M. A significant factor that should be noted is that both direct mission funding and customer funding are increasing.

Customer Focus

The primary mechanisms for review and coordination of ARL's near to mid-term research efforts are Science and Technology Objectives and Technology Planning Annexes. Robust research efforts in these areas are key indicators of program vitality.

ARL is a major contributor to the Army Science and Technology Objective (STO) Program. STOs are the critical fundamental "building blocks" of the Army S&T Program that will enable Army Transformation. The Army Science and Technology Master Plan defines a STO as a research effort that "states a specific measurable (by technical readiness levels), major

technological advancement to be achieved by a specific year. It must be consistent with the funding available in the current year budget, the Future-Years Defense Plan (FYDP), and the Program Objective Memorandum (POM)." The Army limits the number of STOs to 200 or less. In FY2001, ARL was involved in 49 of 186 STOs.

ARL coordinates its research efforts with the Army Materiel Command Research, Development, and Engineering Centers, its primary technology customers. Technology Planning Annexes (TPAs) are the instruments that document the agreements reached between ARL and individual technology customers about what research ARL is to perform. They are negotiated annually during the program formulation cycle and are agreed to and signed by both ARL and the customer. They include a detailed description of the research to be performed, all deliverables, schedules, and the required resources. TPAs can be multiyear, with the deliverables and the required resources spelled out for each year of the multiyear TPA. In signing the TPA, ARL commits to investing these resources and performing the described research. Customers, in signing the TPA, concur that the research is of benefit to their organizations' programs. TPAs totaling $108M in 116 focused programs were in effect for FY2001.

The ARL Federated Laboratory

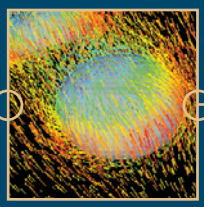
ARL revolutionized Government laboratories' pursuit of research in FY1996 with the creation of the Federated Laboratory (FedLab) concept. The FedLab strategy focused in-house laboratory research on Army specific business areas while establishing extramural centers of research where state-of-the-art expertise could be leveraged to satisfy Army technology needs. Three consortia in the areas of Advanced Sensors, Advanced Telecommunications and Information Distribution, and Advanced Displays and Interactive Displays were established with ARL, industry, and academia as the members, to draw upon the best of the public and private sectors. The five-year FedLab efforts ended in 2001. Space constraints preclude listing all technologies developed in the FedLabs, but indicative of their contributions are: 76 patent disclosures, 302 peer reviewed journal articles, 983 scientific and technical presentations and publications, and significant assistance in strengthening the academic offerings of FedLab HBCU/MI partners in establishment of a new Doctoral Program in Industrial Engineering at North Carolina A&T and new Masters and Doctoral Programs in Electrical Engineering with a concentration in Communications at Morgan State.

ARL Collaborative Technology Alliances - New Research Initiatives

ARL capitalized on the FedLab experience by expanding and improving the concept with the creation of five Collaborative Technology Alliances (CTAs), which were competitively awarded on May 31, 2001. These new alliances include three efforts related to the FedLab consortia, *Advanced Sensors*, *Advanced Decision Architectures*, and *Communications and Networks*, and the establishment of two additional new alliances in *Robotics* and *Power and Energy*. All five will focus on technologies critical to the Army Transformation.

Total CTA funding is $300M projected over eight years for the Cooperative Agreements. There is also a task order contract linked to each Cooperative Agreement to facilitate scientific and technology transitions. One significant change from the FedLab is the opportunity for other government agencies to be a part of the consortia.

BASIC RESEARCH



The ARL Basic Research program focuses on scientific advances in three areas to achieve the Army's strategic research objectives: overcoming technology barriers (customer oriented research), exploiting scientific discoveries (opportunity driven research) and advancing multiple technologies and operational capabilities (both customer oriented and opportunity driven research). These advances are achieved through the collaboration of Army, academic, and industry scientists.

CHEMISTRY

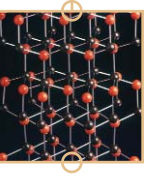
Solvent Resistant Elastomers and Higher Tg Materials from the Same Carbosilane Backbone

The goal of this research is to exploit a new class of polymers – carbosilanes – that can combine the properties of conventional carbon-based polymers with silicon-based materials. The opportunity exists to create a "base polymer" that can be tailored either for elasticity or for pure plastic behavior. The investigator's initial research has demonstrated the proof-of-principle; both types of elastic and pure plastic materials can be made from the same copolymer structure, depending upon the amount of each monomer that is present. The strategic approach uses "latent" reactivity in the polymer backbone, which permits the proper shaping of the material before it is cured in place. The curing takes advantage of the latent reactive site; this site is activated with water at or above room temperature. Presently, they are investigating factors that will enhance the mechanical properties of these polymers.

Important factors being explored include the run lengths between crosslink points in the elastomer, the type of latent crosslink (chlorosilane or methoxysilane), the type of catalyst used in triggering the latent reaction, and the thermal stability of the entire matrix. The goal of this research is to target properties of interest and prepare a wide variety of useful polymers from a "base" starting material. The polymers generated in this program range from flexible to hard and are extremely chemically resistant. They are relevant to a variety of DoD applications, including hoses, belts, mounting structures for vehicles, facemasks, and materials for Electromagnetic (EM) shielding of electronics.

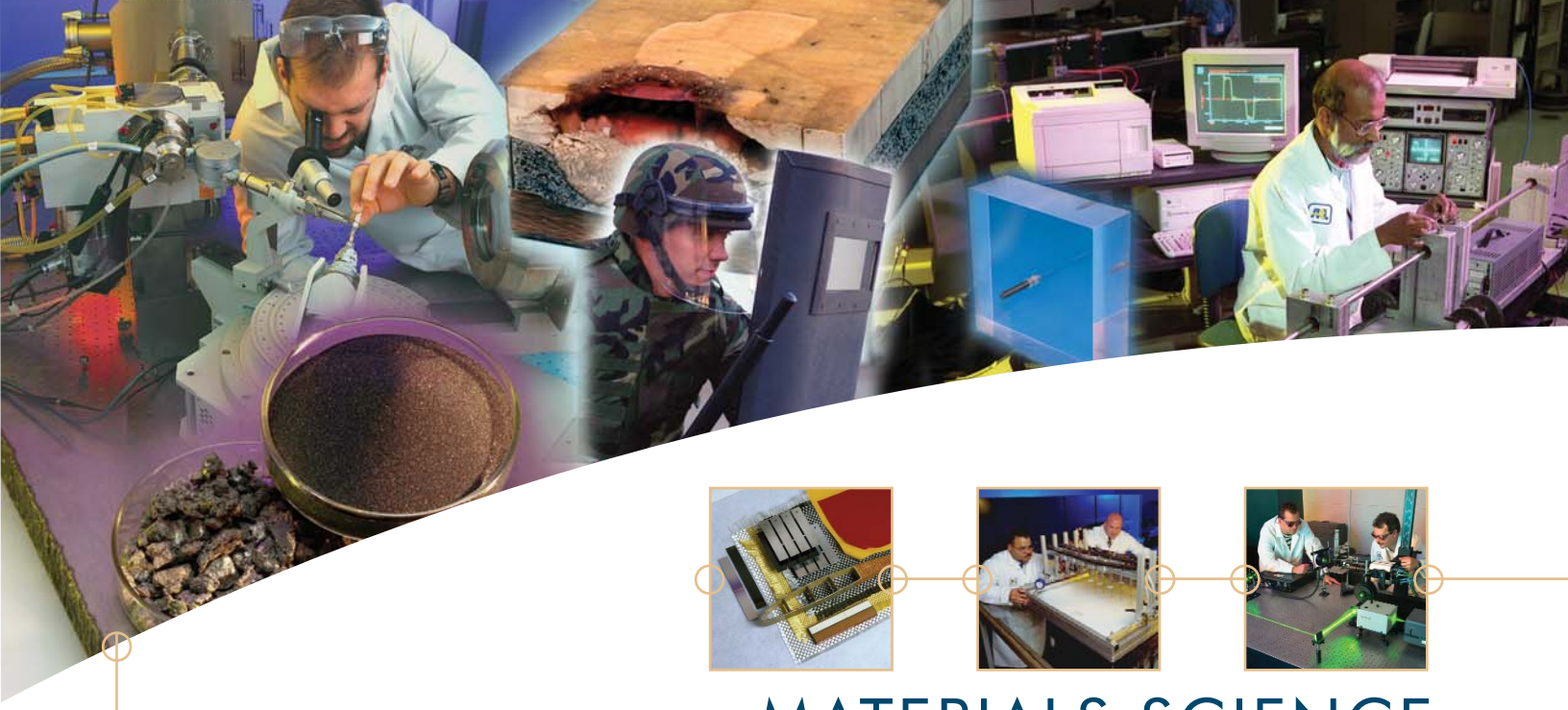
Illustration: University of Florida: The flexibility of a carbosilane polymeric material.

CHEMISTRY



Nerve Agent Sensor Wipe: ARL-sponsored research at the University of Pittsburgh, in collaboration with Agentase, has developed a stoplight colored chemical wipe for the detection of nerve agents. The wipe uses a pH balancing coupled enzyme system to maintain the appropriate pH in diverse environments. The presence of butylcholine esterase inhibiting nerve agents disrupts the coupled enzyme system that yields a change in pH responsible for the color change.

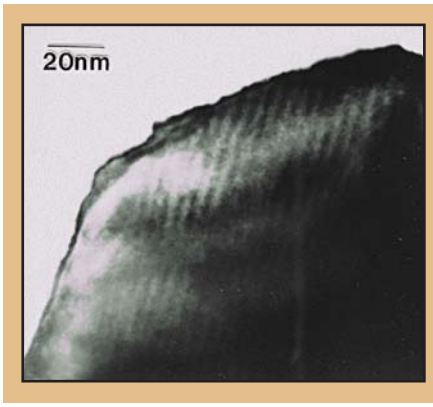
This new wipe enables the detection of low volatility nerve agents on surfaces. Major obstacles that were overcome in this research were incorporation of the enzymes into materials while retaining activity and developing a system that was immune to pH changes not relevant to the presence of nerve agent. The color-based indicators in the wipe are sensitive to pH and a catalytic buffering system has been developed to overcome this sensitivity. If the sensor is dipped in basic solution, one of the enzymes works to bring the pH at the sensor back to its original pH optimum. The sensor surface is wiped across the surface of interest and acts both as the sample collecting surface and the sensor.



MATERIALS SCIENCE

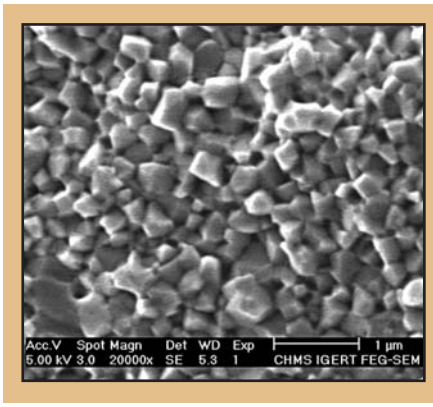
AlN-SiC Nano-Modulated Composites

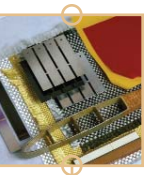
SiC has over 250 different polytypes. Spontaneous transformations between these polytypes are common and can lead to exaggerated grain growth, which can degrade mechanical properties and limit material use. AlN is known to stabilize the 2H structure of SiC at high temperatures. At low temperatures the AlN-SiC system is immiscible, which leads to precipitation of the AlN and transformation of the SiC to the stable cubic structure. It has been demonstrated, however, that the 2H structure can be maintained in a modulated system produced by spinodal decomposition of the solution. Conventional processing requires about 10 hours to form the solid solution and several tens of hours to realize the spinodal decomposition. By using field activation techniques, ARL-sponsored researchers at the University of California-Davis have been able to form this structure in minutes. A composition of 58% AlN results in a microstructural modulation at a scale of about 5nm. In bulk form, the resulting material has a more uniform, refined microstructure and superior mechanical properties than conventional SiC, making it more suitable for demanding structural and/or armor applications.



Piezoelectric Toughening of Nanocrystalline Ceramics

A novel method for toughening a material is to take advantage of the piezoelectric effect, introduced through a minority second phase. As the composite is loaded, the piezoelectric phase develops a charge, which dissipates into the matrix. During subsequent unloading, the charge migrates back through the matrix to return to the piezoelectric phase. During fracture or rapid crack propagation, large currents are generated, which can dissipate large amounts of energy and significantly toughen the material.





Unfortunately, in ceramics this effect is only significant when the particles are very small and very close together – literally on the nanoscale. This level of nanoscale processing is difficult to achieve, especially in a piezoceramic nanocomposite. Spark-plasma sintering techniques were used to create $Nd_2Ti_2O_7$-Al_2O_3 nanocomposites. It was initiated with $Nd_2Ti_2O_7$ powders and a commercial 50nm -Al_2O_3 powder. The powders were mixed in a ball mill and then pressed at ~1000°C for less than two minutes to produce high-density material with an average grain size of 280nm. The mechanical properties are shown in the table below, along with several other materials for comparison. In comparison to other alumina nanocomposites, a dramatic improvement in fracture toughness was observed in the piezoceramic materials, suggesting that the "piezoelectric effect" can be very effective as a toughening method in nanocrystalline alumina ceramics. The highest toughness was achieved in the Al_2O_3-2 mol.% $Nd_2Ti_2O_7$ composite, indicating that there is an optimum concentration of the second piezoelectric phase for toughening nanocrystalline alumina. Eventual applications of this technology might include armored ceramic windows and high toughness optical components for smart munitions.

Physical and mechanical properties of alumina nanocomposites

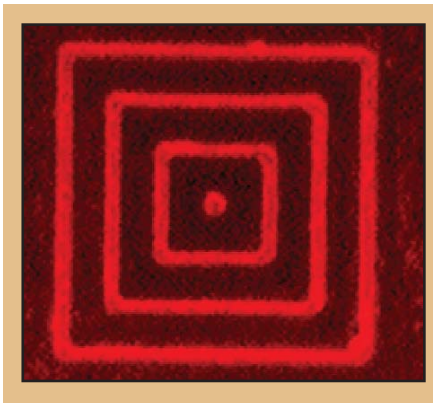
Material	Processing method	Grain size (nm)	Hardness (GPa)	Fracture toughness ($MPam^{1/2}$)
Al_2O_3-2 mol.% $Nd_2Ti_2O_7$	EFAS	279	15.5 ± 0.75	7.86 ± 0.51
Al_2O_3-3 mol.% $Nd_2Ti_2O_7$	EFAS	396	16.0 ± 0.89	5.79 ± 0.37
Al_2O_3-10 vol.% SiC	HPS	101	19.6 ± 0.22	2.96 ± 0.91
Al_2O_3-2 vol.% ZrO_2	HPS	117	23.1 ± 0.74	2.80 ± 0.55
Al_2O_3-10 vol.%	HPS	106	24.7 ± 0.56	3.49 ± 0.97
Diamond AD999 Al_2O_3	—-	3000	20.1	2.32 ± 0.07

EFAS: spark plasma sintering; HPS: high pressure sintering

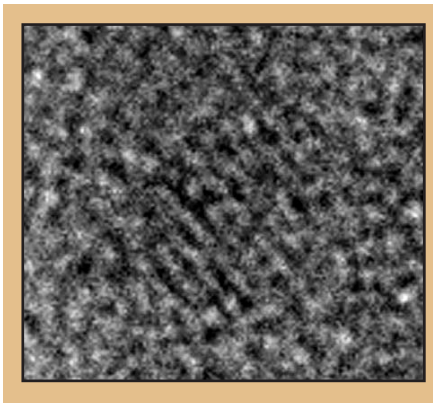
LIFE SCIENCES

Biomolecular Recognition of Semiconductors and Magnetic Materials to Pattern Quantum Confined and Magnetoelectronic Structures

Research aimed at the design of biologically based building blocks for nucleation and patterning of electronic and magnetic materials on nanometer-length scales in 2D and 3D structures, using tools from nature, enables the hierarchically ordered construction of faster and more efficient sensor and electronic device elements. The selection of peptides with high affinity for specific semiconductor structures and crystal orientations using molecular recognition, together with rational design of peptides and peptide block polymers to bind and assemble semiconductor and magnetic nanoparticles, is the key approach for fabrication of structures impacting the design and manufacture of macroscopically ordered addressable storage arrays or circuits, light emitting displays, optical detectors and lasers, and fast interconnect nanometer scale computer components.



ARL-sponsored researchers at the University of Texas have identified peptides that select for and specifically bind to inorganic semiconductor nanoparticles or nanoparticles of iron and tin oxides. The goal is to be able to spatially and temporally nucleate inorganic structures via selectivity and recognition to control size, distribution, and assembly for the patterning and interconnection of electronic and magnetic materials on nanometer length scales. Shown on the top right is recognition of III-V semiconductor materials by one member clone of a phage display library, a combinatorial library of biologically evolved random peptides, where that one peptide is able to select and specifically bind electronic materials. The fluorescently labeled phage clone is bound to GaAs (concentric orange pattern), but not to the surrounding SiO_2. On the right is the lattice image

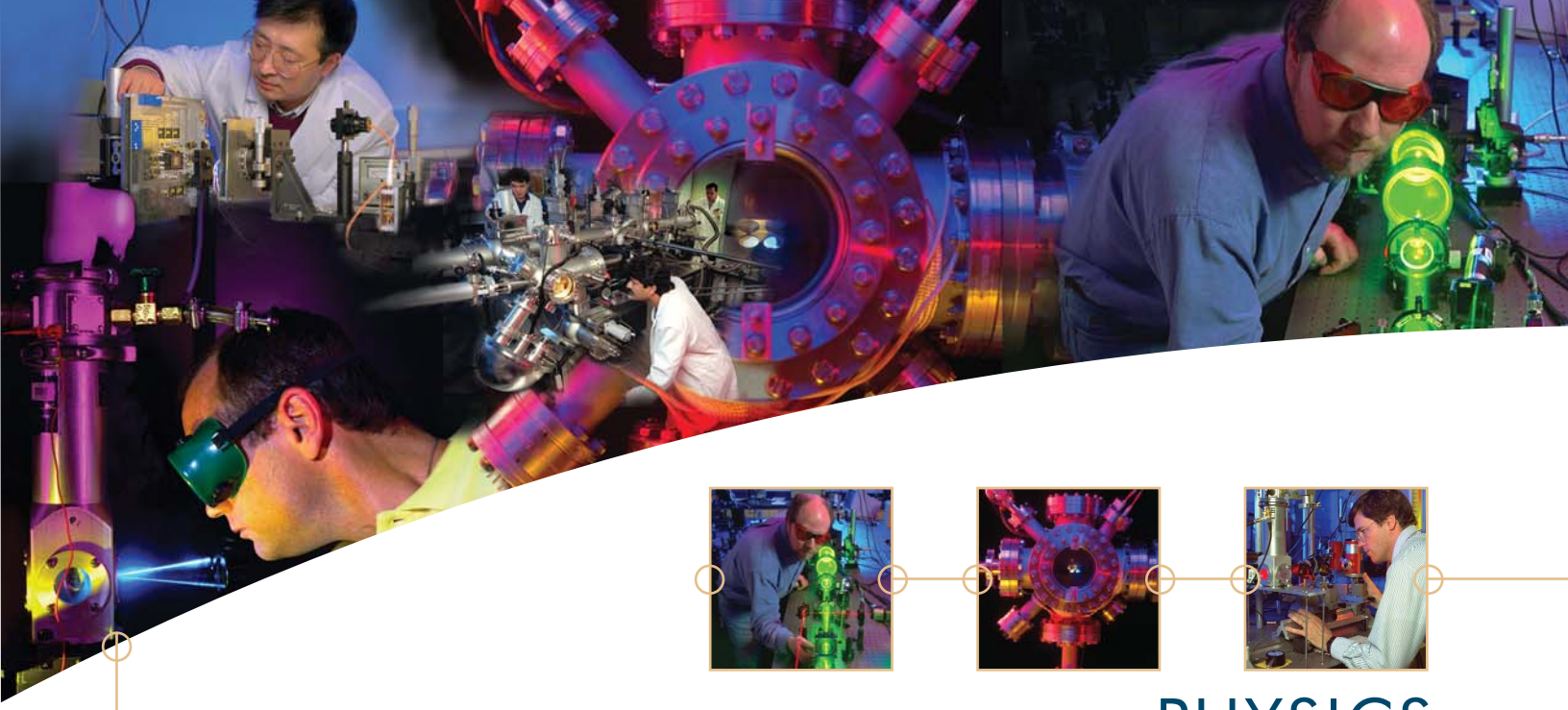


of a ZnS nanoparticle that was grown with another peptide generated through a phage display library where production of peptide was constrained relative to the amino acids making up the structure. The stripes in the nanoparticle represent the (100) lattice planes that are 3.3 angstroms apart.

High Selectivity Detection of Biologicals

For a stronger defense posture against biological threats, high selectivity detection is enabled by innovative interdisciplinary research to generate sensor elements, or receptors, such as antibodies or nucleic acids or their mimics. These elements can recognize threat targets with very high affinity and specificity, and tie these functionally to efficient signal transducer elements in patterned array systems. Biosensing elements are conjugated to small beads that are in turn introduced into micro-machined wells. An integrated optics package allows interactions with the individual elements to be identified and quantified. The advantage of this platform is its ready manufacturability, in that beads, chips, and optics can be produced separately in bulk and then configured for the detection of particular analyte sets or classes of analytes.

To generate an 'omni-sensor' that could detect a wide variety of agents, researchers at the University of Texas first developed multiple types of molecular sensor elements and achieved their high-throughput production. These provide for wide biochemical coverage, including solutions that change pH in the presence of pathogens, allowing colorimetric detection; enzymes that recognize and inactivate toxins; nucleic acids that sense the genomic DNAs of many different pathogens; and antibody sensors that detect anthrax spore coats. Sensitivity is in the nanomolar to micromolar range. Beads are derivatized with the multiple sensor elements and placed into micromachined arrays of wells in a silicon substrate. Because the sensor elements are in discretely separated wells, rather than on a chip surface, and because microfabrication techniques allow fluidic delivery to the wells, the approach can use extremely sensitive solution-phase reactions to detect agents, rather than relatively insensitive surface-phase reactions.

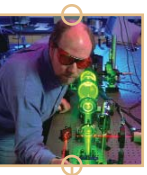


PHYSICS

Infrared-Absorbing Silicon: New Possibilities for Infrared Detection

Silicon is the basic substrate of microelectronics and the material of choice for many optoelectronic devices such as solar cells and photodetectors. However, ordinary silicon is nearly transparent to infrared light at wavelengths longer than 1.1 μm, a region of great importance for remote sensing and telecommunications. An ARL-sponsored research group at Harvard University has developed a novel way of microstructuring Silicon Carbide (Si) with femtosecond laser pulses which results in near-complete absorption of incident light from the near ultraviolet (0.25 μm) to the near infrared (2.5 μm). Preliminary measurements indicate that the microstructured material enhances infrared light detection at 1.064 μm, a wavelength at which ordinary silicon devices are insensitive because of its proximity to the band gap, and 1.3 μm, a wavelength at which silicon ordinarily detects no light whatsoever. Infrared detectors made with microstructured silicon open up the possibility of fundamentally changing infrared detection technology, such as that used in the telecommunications industry, since such devices could easily be incorporated into integrated circuits. No previously reported modification of silicon achieves near-unity light absorption over so broad a wavelength range, and none reports significant absorption of infrared radiation.

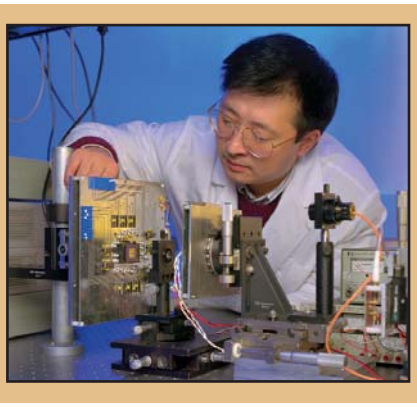
The surfaces are microstructured by irradiating a crystalline silicon surface with 800 nm laser pulses (500 μJ, 100 femtoseconds in duration) from a regeneratively amplified Ti:sapphire laser in the presence of 500 torr sulfur hexafluoride (SF_6). This process creates an array of sharp conical spikes up to 40 μm high that are about 0.8 μm wide near the tip and 10 μm wide near the base. After five laser pulses, the surface becomes grainy; upon further irradiation, the grains evolve into 20-μm tall spikes. The spikes

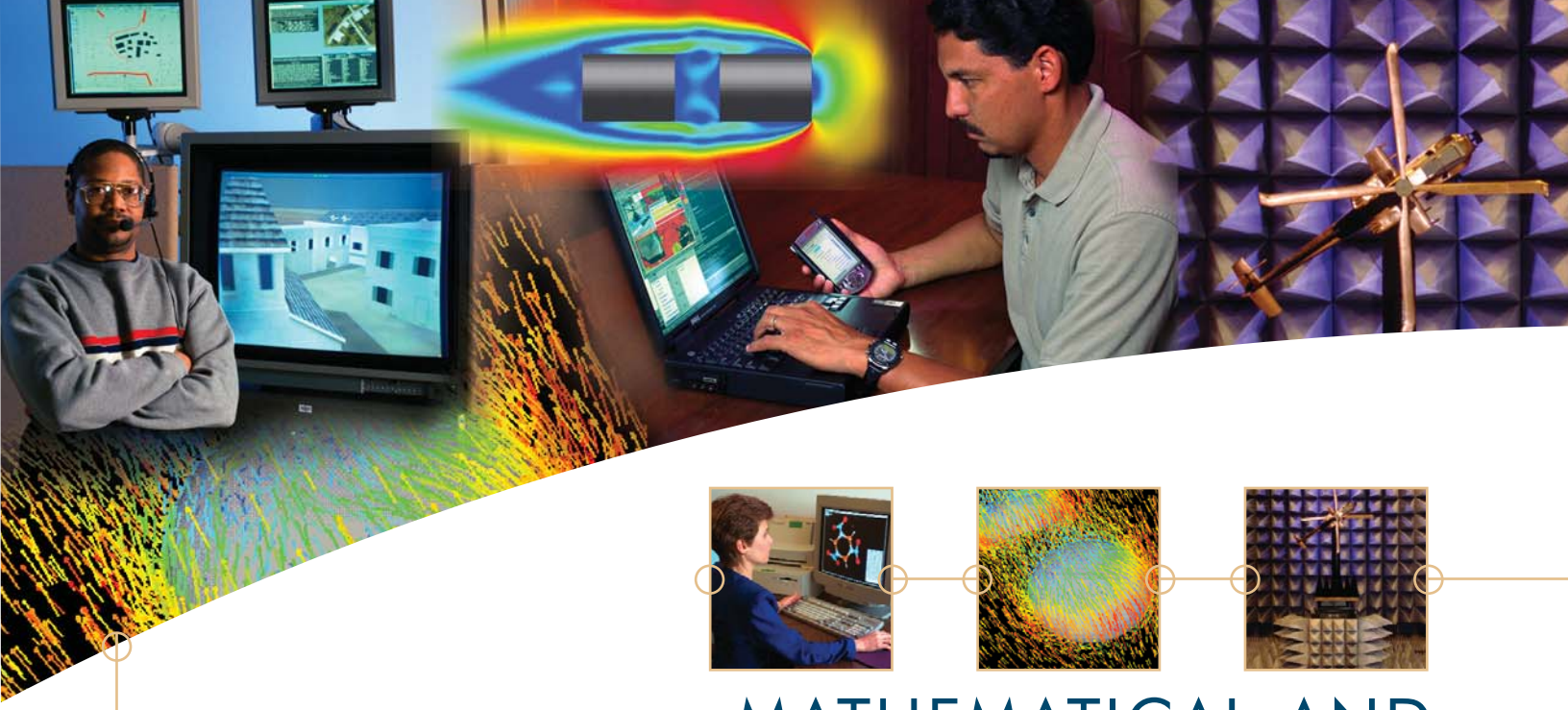


form only in the region illuminated by the laser. In addition to high absorption, these surfaces also have many other possible applications: efficient field emission for plasma displays; microneedles for transdermal drug delivery; photoluminescence for light-emitting elements devices; and silicon surface roughening to promote adhesion of other materials.

Simplified DNA-Based Detection of Anthrax

ARL-sponsored researchers at Northwestern University have developed a new class of nanoparticle-based sensors for DNA detection that have greater selectivity and three orders of magnitude greater sensitivity than conventional methods. These sensors use the intense optical absorption (colors) of gold nanoparticles, together with the extraordinary selectivity of DNA hybridization (only complementary DNA strands will bind) to develop an assay for DNA recently used to detect anthrax and tuberculosis. Moreover, the technology for using gene chips in conjunction with the nanoparticle sensors has now been developed, making it possible to do rapid, specific, simultaneous tests for thousands of pathogens. This technology may eliminate the bulky, expensive, and time consuming polymerase chain reaction (PCR) amplification of DNA used in all conventional DNA detection. In addition to reducing cost, the nanoparticle sensors may enable compact, portable detection of pathogens under battlefield conditions or for antiterrorist activity. A small company, Nanosphere, Inc., has begun to commercialize this technique, particularly to the medical industry. In addition, the Army has tested this technique at Dugway Proving Ground, Utah, as part of its assessment of innovative biological agent detection methodologies. Preliminary results look very promising.





MATHEMATICAL AND COMPUTER SCIENCES

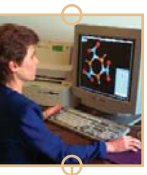
Source-Coupled Adiabatic Logic with Diodes

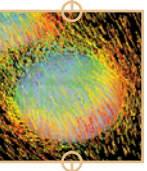
Using a standard CMOS (Complementary Metal Oxide Semiconductor) process, an ARL-sponsored researcher at the University of Michigan has developed logic circuits with true single-phase power clock operation and a simple on-chip power-clock generator. The circuits are straightforward to cascade and have a tunable current source at each gate to reduce critical dissipative current levels at critical times. The circuits achieve efficient operation over a broader range of frequencies than do the traditional design techniques. Results to date show higher energy efficiency than static CMOS and other adiabatic logic families. Design, fabrication, and testing of an adiabatic 8-bit multiplier chip in 0.5mm standard CMOS process has been performed and demonstrates 2-4x less dissipation than corresponding CMOS in the 50-200MHz range. This experiment validated correct and efficient operation, and Intel Corporation has applied for a patent. These logic circuits provide the highest efficiency compared to other energy conserving circuit techniques. The gain in energy efficiency enables longer battery lifetime for portable military systems such as computers, radios, and night vision systems. Higher energy efficiency results in longer mission duration time and/or lighter battery weight for the soldier's load due to fewer batteries needed to complete the mission.

Accurate, Data-Compressed Representation of Natural and Urban Terrain by L_1 Splines

The development of shape-preserving techniques for smoothly representing data is a major objective in modeling of terrain, geophysical features,

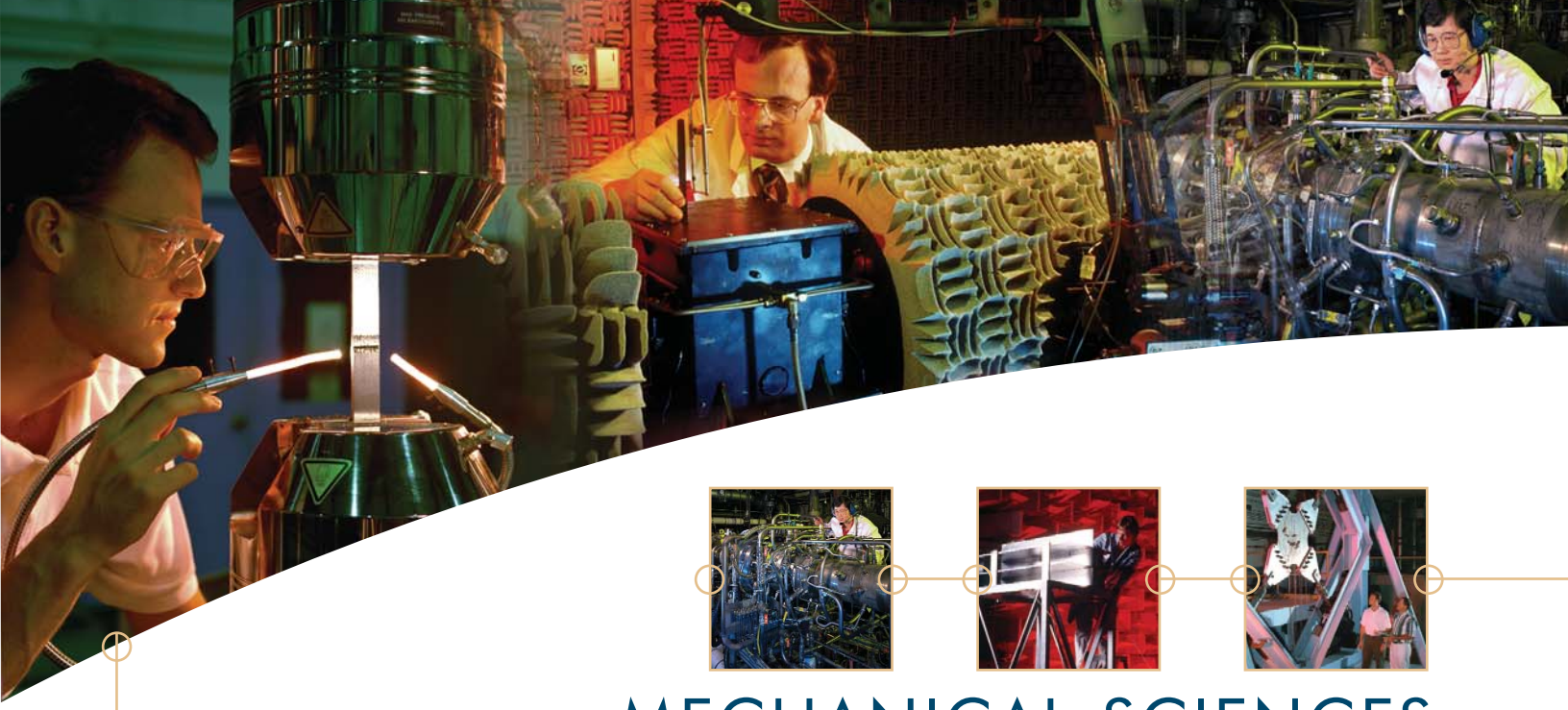
MATHEMATICAL AND COMPUTER SCIENCES





geography, biological objects, mechanical objects, and many other irregular surfaces and functions. A multitude of variants of conventional tensor-product, box, polynomial, thin-plate, rational and network splines perform well on many types of data. However, none of these procedures provide, without human intervention, smooth representation of irregular surfaces free of extraneous overshoot and oscillation.

Recently, a new class of "L_1 splines" was discovered. The coefficients of L_1 splines are calculated by minimizing the integral of the absolute value of the second derivative (that is, the L_1 norm of the second derivative, hence the name L_1 splines). In contrast, conventional splines are calculated by minimizing the integral of the square of the second derivative. L_1 splines provide smooth, shape-preserving representation of arbitrary data, including data with abrupt changes in magnitude and spacing without the extraneous overshoot and oscillation seen in conventional splines. Computer codes for univariate and bivariate L_1 interpolating and approximating splines were provided to ARL and have been used for modeling urban terrain for calculations of dispersion of terrorist-released biochem agents. L_1 splines are a foundation for accurate, real-time visualization with large dynamic range and with continuous, glitch-free zoom-in/out.



MECHANICAL SCIENCES

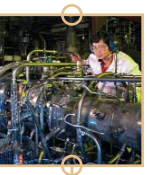
A Novel Approach to Large Electrostriction in Ferroelectronics

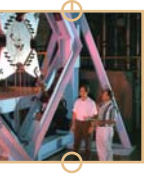
Ferroelectric materials are currently used in a variety of sensor and actuator applications. Conventional materials offer a high frequency, linear response with useful strains of up to 0.1%. This work addresses the research needed to develop new structural and mechanical applications that were previously limited by the amount of strain, and it could lead to large strain actuators to reduce the size of existing systems. This research uses newly developed finite-deformation micromechanical formulations and experiments to investigate methods to obtain and control very large electrostrictive strains in ferroelectric materials. Thus far, the investigators have obtained strains in single crystal ferroelectric ceramics (barium titanate, $BATiO_3$) that are almost an order of magnitude larger (~0.8%) than other materials used to date, and they have predicted strains as large as 5% for polycrystalline ferroelectrics. The large electrostriction produced in this research effort may lead to the development of strain and displacement sensors and electromechanical actuation devices for large force and/or stroke needed for structural shape change and desired material response.

Experimental Investigation of the Interaction of Electrothermal Plasmas with Solid Propellants

This program is performing a detailed experimental study of a plasma and its interaction with representative solid propellants. The objective is to develop an extensive experimental database of species concentrations both during the plasma-propellant interaction and immediately thereafter. Such a database is vital to develop a correct thermochemical model of mechanisms that lead to rapid, repeatable ignition of the propellant.

MECHANICAL SCIENCES





Time resolved, simultaneous multi-point measurements, supplemented with line-of-sight averages and single-point measurements, are being made of temperature and species distributions in the plasma-propellant flowfield. The characterization of the pulsed plasma jet is accomplished using a variety of optical diagnostics. A gated-intensified CCD camera is used to capture images of visible emission and Schlieren images.

In addition to the imaging studies, instantaneous emission spectra investigate evolution of the excitation temperature and electron density fields. Planar laser-induced fluorescence (PLIF) is used to obtain two-dimensional images of species in the flowfield. The figure below shows a PLIF image of copper atoms (from the igniter fuse wire and electrode). The PLIF image of atomic copper was obtained by pumping the $^2P_{3/2} \leftarrow {}^2S_{1/2}$ line at 327 *nm* and detected the fluorescence from the $^2P_{3/2} \rightarrow {}^2D_{5/2}$ line at 578 *nm*. The image was obtained by subtracting two 17-shot averages in order to remove the intense background emission from the plasma.

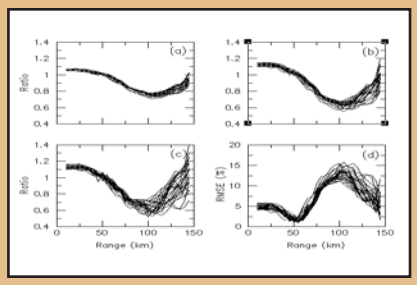
Grey scale image of Cu atoms detected by PLIF. The excitation laser beam is passing from left to right and is retro-reflected.

ENVIRONMENTAL SCIENCES

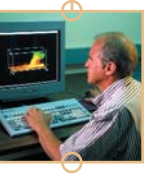
Studies of Radar-Rainfall Error Propagation in Runoff Prediction

Weather radars, like the Weather Surveillance Radar-1988 Doppler (WSR-88D), produce quantitative precipitation estimates in real-time, but rainfall rate estimates derived from such radars are contaminated by a host of random and systematic errors. The objectives of this ARO Young Investigator Program research project, completed during FY2001, were to understand the impact of weather radar rainfall estimation errors in runoff hydrographs calculated from the physically based, distributed rainfall-runoff model *CASC2D,* and to determine hydrologic prediction error limits as a function of radar platform, random and systematic error source, and storm and precipitation type.

The effects of radar range and orientation and other systematic and random error sources were studied by simulation of storms and simulation of the radar observation process. A radar simulator was used to observe storms simulated by a state-of-the-art atmospheric model (*ARPS*). The pure effects of radar range and orientation on radar estimates were quantified along with combined effects of range/orientation and other error sources. The quality of adjusted radar-rainfall estimates, using conventional approaches, was analyzed. Hundreds of storm realizations over a 22 km^2 watershed were analyzed to study the statistical properties of the propagation of radar-rainfall uncertainty through runoff predictions. The deterministic hydrologic model *CASC2D* was used to translate radar-rainfall precipitation estimate input uncertainty into hydrologic uncertainty within a Bayesian framework.



Dependence of radar-rainfall and runoff errors on range and orientation for: (a) rainfall volume, (b) runoff volume, (c) peak discharge, and (d) hydrograph root-mean-squared-error.



Studies of the Stable Boundary Layer Using the High-Resolution Doppler Lidar

The high resolution scanning, Doppler lidar developed by the National Oceanic and Atmospheric Agency and ARO was deployed in the Cooperative Atmosphere-Surface Exchange Study near Leon, Kansas, under ARO sponsorship. Researchers operated the eye-safe (2.06 m wavelength) lidar system in various modes during study periods and conducted analyses of the structure of low altitude wind fields in stably stratified boundary layers. This system was invaluable in helping define the structure of the boundary layer winds spatially and temporally. It is an integral part of ongoing research into the evolution of nighttime boundary layers.

The lidar was shown to be a highly versatile tool for atmospheric boundary layer research and operational applications. Spatial inhomogeneities in the wind speed and direction have been detected and analyzed, and profiles of turbulent structure of the boundary have been developed from the measured data. The system is essential for studies of atmospheric processes, especially near the ground, required to obtain data to improve high resolution modeling of atmospheric processes.

ELECTRONICS

Ultrafast Optical Communications

ARL-sponsored research is continuing at Purdue University in the field of ultrafast optical communications. Funding is aimed at developing compact and fieldable optical systems that will far surpass current capabilities of normal fiber-based communications. The systems will also have the ability to produce secure communications via encryption at the physical layer (as opposed to software). Advancements in this project have come specifically in the area of compactness. Arrayed waveguide gratings, commonly used in dense wavelength division multiplexing systems, have been used as a substitute for bulk optics based lens/grating space-time converters. This means that pulse-shaping systems as outlined will be possible to manufacture out of integrated rather than bulk optics. Anticipated accomplishments include replacement of the current array with faster modulators.

GaN-Based Micro-LEDs and Micro-Photodetectors

Researchers at Kansas State University sponsored by ARL have succeeded in making high efficiency micro-LEDs based on GaN heterostructures containing InGaN quantum wells. The LEDs are fabricated into arrays that produce bright blue lights for flash lights, microdisplays, optical disk drives, etc. Making the LEDs smaller in diameter increases the extraction efficiency so that higher light outputs are obtained for a given area. Miniature detector arrays are also being fabricated which are sensitive to UV radiation. A quaternary alloy, AlGaInN, is utilized for its reduced strain and improved photoresponse. A five-times improvement in responsivity using this alloy shows the progress already made.

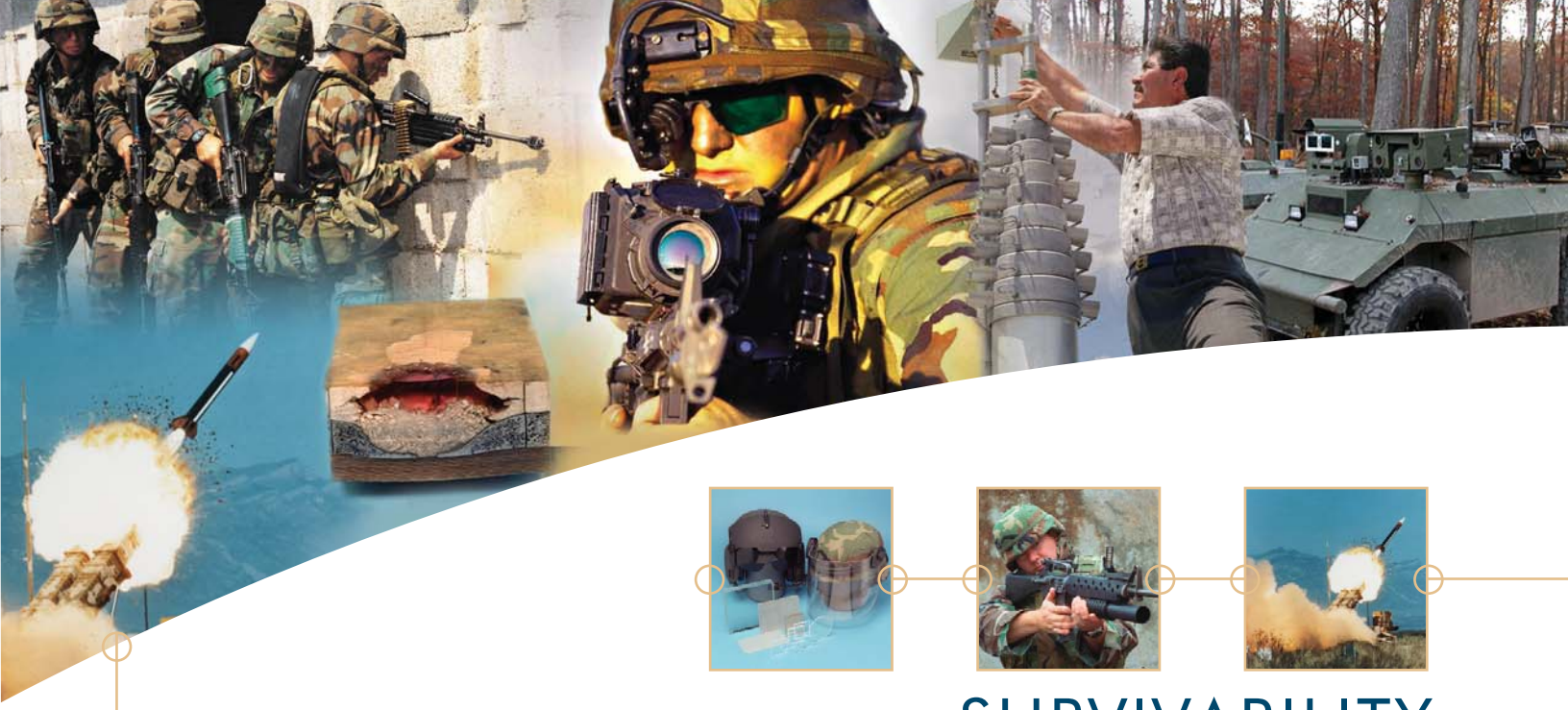

CARCO ELECTRONICS

APPLIED RESEARCH



ARL's applied research program develops technology opportunities and evaluates their technical feasibility for increased operational capability. Applied research includes all efforts directed toward the solution of specific military problems, short of major program demonstrations and development projects.

At ARL, the applied research program includes the development of components, models, and new concepts through in-house and industry efforts. Individual research programs often enable a variety of new systems and support a number of identified needs.

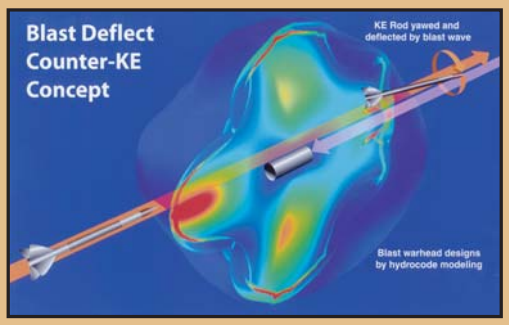


SURVIVABILITY

Provide innovative technologies to enable a lightweight, survivable Objective Force

ARL provides the majority of the survivability and lethality science and technology which makes the individual soldier and the Army's future weapons systems more lethal, survivable, and strategically deployable. Research efforts in weapons and materials focus on the Army's unique and emerging needs for advanced armor and armaments technologies. In partnership with the RDECs, industry, national laboratories, and academia, as well as the appropriate foreign institutions, ARL provides Future Combat Systems (FCS) and the Objective Force with technology that is essential to the soldier and to future lightweight combat vehicles.

One of the most difficult challenges is to ensure that the family of 20 to 30-ton future ground combat vehicles envisioned for the Objective Force has the same survivability provided in the current 70-ton Abrams main battle tank. ARL is executing an aggressive research program to provide technologies for active protection (AP) against large caliber kinetic energy penetrators, as well as lightweight integrated armors/structures to defeat the residual from large caliber kinetic energy (KE) penetrators defeated by AP, and the increasing medium caliber threat.



Blast Deflect Counter-Munition Concept designed using hydrocode modeling and validated on ARL's Transonic Experimental Facility.

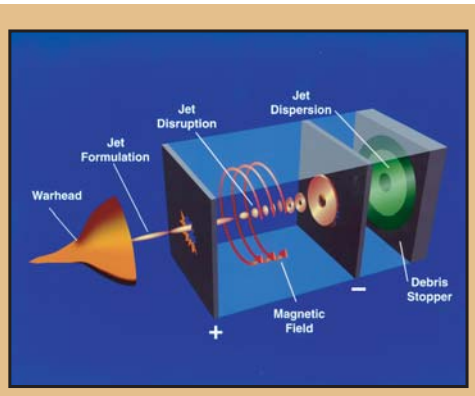
Kinetic Energy Active Protection Technology

The ARL is leading the Army effort to develop enabling technologies for Kinetic Energy Active Protection Systems (KEAPS). The goal of KEAPS is to move the engagement envelope for the defeat of tank-fired KE rounds beyond the outer skin of the vehicle.

This will enable Future Combat Systems with ballistic survivability that exceeds that of existing ground combat vehicles using relatively light armor structures rather than the usual heavy passive armors. During FY2001, ARL performed full-scale experiments that demonstrated the feasibility of using blast warhead and contact-fracture counter-munitions to cause severe deflection or damage to an incoming KE threat. System-level assessments and physics-based models were developed and used to determine high payoff component technologies. In addition, experimental validation proved the capability to successfully detect and track KE threats with the required accuracy (including arrival time and location) using passive infrared sensor technology. The joint ARL/TACOM Full Spectrum Active Protection (FSAP) Program is currently on track to provide FCS and the Objective Force with an integral FSAP system that provides hemispherical protection against KE, anti-tank guided munitions, hand-held infantry weapons, and sensor-fuzed munitions.

Ballistic Protection for Future Combat System

The joint ARL/TARDEC Ballistic Protection for FCS STO (Science and Technology Objective) is aimed at providing revolutionary, lightweight ballistic protection for a survivable FCS. The objective of the STO is to integrate advanced materials, structures, and armor concepts to provide lightweight protection against future medium caliber cannon threats, residual from Active Protection defeat of large caliber KE rods, light and medium shaped charge threats, top attack weapons, and mines. ARL has experimentally demonstrated revolutionary multi-stage armor configurations that defeat RPG, automatic cannon, and residual from APS threat surrogates at or below FY2001 STO weight goals. Electromagnetic (EM) armor technology has been matured to enable defeat of shape charge threats. The performance of ceramic armor technology against automatic cannon threats has been increased by more than 50% since FY1999. In addition, structural armor configurations have been experimentally validated that defeat heavy machine gun and artillery fragment threats at FY2001 STO weight goals. Moreover, critical numerical and analytical models have been validated with these experiments. The current program is on track for a Technology Readiness Level (TRL) 6 demonstration at required weights by FY2004. Toward this goal, ARL and TARDEC have initiated integration of EM armor technology onto a surrogate platform and begun necessary development of power componentry. These efforts have been briefed to the Chief of Staff of the Army and are clearly on the critical path to ensuring an FCS with ballistic survivability that exceeds that of existing ground combat vehicles.



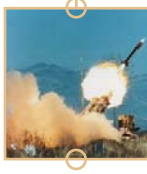
Electromagnetic Armor Concept.

Low Cost Composite Materials Processing Technology

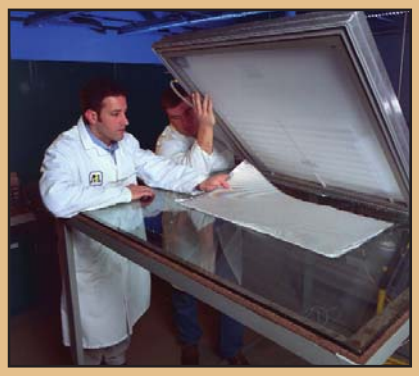
Future Combat Systems and other Objective Force platforms require both low cost and superior performing composites to ensure that they will be lightweight and survivable. ARL's Novel Low Cost Composite Armor and Army Vehicle Material Manufacturing Process STO will deliver an improved process for affordably and reliably infusing multifunctional composite materials, as well as a new process of fabricating low cost, large scale preforms. During FY2001, ARL experimentally validated a new process entitled FASTRAC, which has outperformed conventional Vacuum Assisted Resin

SURVIVABILITY





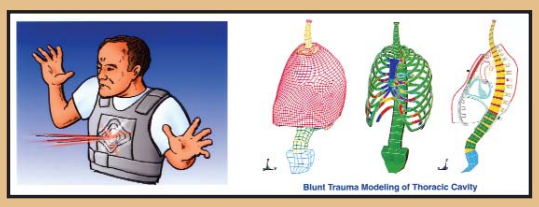
Transfer Molding (VARTM) in every metric. In a collaborative effort with United Defense Limited Partnership, the infusion rate using the FASTRAC process was 23% faster than the VARTM process in the production of multi-material (ceramic, elastomer, and polymer composite) blow off panels for the Crusader, and it provided a cumulative cost savings of 24% for labor. Further labor savings are anticipated by improving the design of the FASTRAC media and reuseable bag (total 30-40%). The models and processing technologies will be further validated in FY2002 and transitioned to the Knowledge and Process Tools for Manufacturing of Affordable Composite Structures Manufacturing Technology Objective (MTO). These technologies will provide affordable, rapid prototyping and manufacturing processes for FCS and Objective Force, as well as for near-term development programs such as Comanche.



FASTRAC enables significant savings by eliminating process steps.

Ballistic Protection for Improved Individual Survivability

ARL is conducting a systematic ballistic experimentation and modeling program designed to provide the Objective Force Warrior (OFW) with revolutionary lightweight, multi-hit protection systems to ensure survivability and sustained operations. During FY2001, as part of the joint ARL/SBCCOM STO on Ballistic Protection for Improved Individual Survivability, ARL has established the baseline armor required to defeat the emerging tungsten-carbide core 7.62-mm armor piercing threat and has identified several integrated materials approaches that show potential to defeat this threat with a 30% reduction in areal density. A first generation blunt trauma model has been developed and has shown reasonable agreement with data from previous Armed Forces Institute of Pathology experiments. In FY2002 and beyond, this model will become part of an overall personnel armor materials modeling effort that incorporates failure mechanisms of projectiles, fabrics, ceramics, composite backing, and behind armor effects to guide future revolutionary lightweight armor designs. In a complimentary effort, Pinnacle Armor was awarded a Phase I SBIR contract for the development of Flexible-Modular Body Armor for Armor Piercing Protection. In collaboration with ARL, a prototype system was successfully demonstrated for the defeat of the 7.62-mm Ball, M80 projectile. Pinnacle Armor's efforts were highlighted by a revolutionary technology called DRAGON SKIN, which appears to be a practical, flexible body armor that can defeat rifle rounds and offer expanded coverage of vital torso areas. Experiments performed at ARL have demonstrated reduced multiple hit separation from 6" to 1", improving multiple hit capability from 4 shots to 12 shots/insert with minimal back face deformation implying lower blunt force trauma. Transition of these technologies to the development community will enable a highly survivable and mobile OFW capable of operating effectively in a full range of military applications.

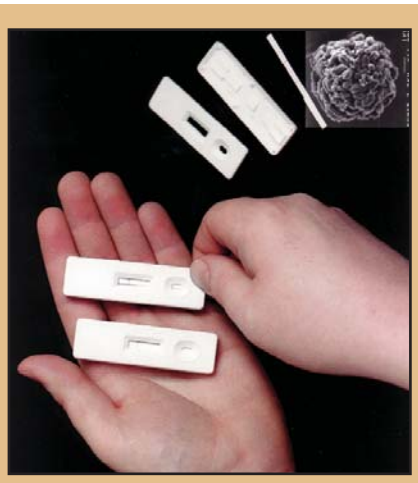


Personnel armor materials modeling methodology.

SURVIVABILITY

Advanced Chemical and Biological Protective Materials Technology

The FCS and the OFW will require revolutionary protection from chemical and biological agents to ensure their survivability and operational effectiveness. ARL is designing, developing, and evaluating materials and material systems for protective clothing, masks, and detection/decontamination equipment in support of the Natick Soldier Center and the Edgewood Chemical and Biological Center of SBCCOM. In collaboration with the Joint Program Office for Biological Defense, dendrimer-based hand held assays that detect biological agents with a single strip/ticket have been prototyped and proven to be more affordable and much more sensitive than existing technology. In addition, molecularly imprinted polymers have been incorporated into sensors that have demonstrated parts-per-trillion detection levels and high selectivity for use in the Joint Service Agent Water Monitoring Program. ARL has also developed methodology to relate surface morphology changes in Chemical Agent Resistive Coatings (CARC) to changes in appearance, thus providing the capability to determine when a system must be re-painted prior to the CARC actually failing. These efforts are critical to providing effective protection of Army personnel and materiel from chemical and biological threats.



Dendrimer-based hand held assays for bio-agent detection.

Unmanned Ground Vehicle Technologies

ARL, in close collaboration with the OSD Joint Robotics Program, is leading the United States effort to advance autonomous mobility technologies for FCS and the Objective Force. This effort will advance key enabling technologies required for a new generation of small, lightweight, unmanned systems for diverse applications, able to maneuver in tactical scenarios at speeds consistent with manned components of a ground maneuver force. In support of the Semi-Autonomous Robotics for FCS STO and the Robotic Follower Advanced Technology Demonstration, ARL integrated perception and control technologies into a group of four Unmanned Ground Vehicle (UGV) testbed platforms, which demonstrated semi-autonomous cross-country mobility at speeds of up to 20 mph (day), corresponding to 50% of the speed of a manned High Mobility Multipurpose Wheeled Vehicle (HMMWV). Robotic follower operation at speeds of 20 mph on-road and 10 mph off-road were also demonstrated.

UGV operating on complex terrain at Fort Indiantown Gap, PA.

The team devised intelligent control strategies and implemented a multilevel (spatial and temporal) World Model to enable UGVs to execute a basic set of military behaviors. New perception techniques (LADAR and Stereo Imaging) were integrated with advanced on-board intelligent vehicle control architecture to attain major increases in autonomous vehicle performance. These performance increases were evaluated on rugged, complex terrain at Fort Knox, Kentucky, and on even more challenging terrain at Fort

SURVIVABILITY

Indiantown Gap, Pennsylvania. All technical and logistical preparations were completed for the Demo III evaluation, which comprises a set of technical and tactical evaluations to examine the maturity of autonomous mobility technologies (scheduled for FY2002 at Fort Indiantown Gap). As ARL looks toward the future, it has established the Robotics Collaborative Technology Alliance, an external research consortium, involving industry, academia and HBCU/MIs to conduct applied research on the topics of perception, intelligent control and man/machine interfaces. The applied research conducted in these programs will be transitioned to technology development, demonstration and materiel acquisition programs being conducted by TARDEC, the OSD Joint Robotics Program, and the other services. ARL is leading the effort to put robotic platforms out front in harm's way, increasing operational reach and force effectiveness, and ensuring the survivability of FCS and the Objective Force.

LETHALITY

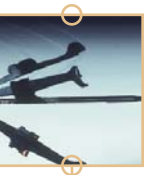
Provide innovative technologies to ensure a lightweight, lethal Objective Force

ARL provides the majority of the survivability and lethality science and technology which make the individual soldier and the Army's future weapons systems more lethal, survivable, and strategically deployable. Research efforts in weapons and materials focus on the Army's unique and emerging needs for advanced armor and armaments technologies. In partnership with the RDECs, industry, national laboratories, and academia, as well as the appropriate foreign institutions, ARL provides FCS and the Objective Force with technology that is essential to the soldier and to future lightweight combat vehicles.

ARL is conducting an aggressive program to develop the enabling technologies requisite for enhancing lethality to ensure combat overmatch for Army Transformation.

Novel Lethal Mechanisms for Guns and Missiles

ARL leads the Army effort to develop advanced penetrator technologies to enable lethal FCS and Objective Force platforms. In the gun technology area, the goal is to increase lethality of penetrators and explosive warheads to meet the escalating threat without seriously increasing the vulnerability of our systems. In FY2001, ARL validated physics-based models with experimental firings that demonstrated the ability of jacketed KE penetrators to defeat FCS threat targets. This technology is currently being optimized for transition to the Armaments Research, Development, and Engineering Center (ARDEC) for continued development under the FCS Multi-Role Armament and Ammunition System Advanced Technology



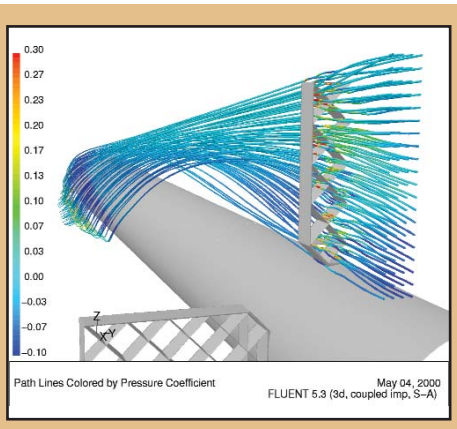
Demonstration (ATD). In the missile technology area, ARL is working toward the goal of maintaining or improving lethality while reducing missile size by 50% over current LOSAT KE missiles. Toward this goal, ARL is executing a combined experimental and computational program to study the effectiveness of kinetic energy missile concepts against selected armor targets. The influence of velocity, structural support configuration, and target geometry on the overall penetration performance of specific lethal mechanisms was quantified with experimental firings. The results of these experiments, which validated parametric models developed at ARL, were used to formulate design guidance for missile component and structural configurations that would maximize the lethality of the Compact KE Missile under development at the Aviation and Missile Research, Development and Engineering Center (AMRDEC).

Insensitive High Energy Munitions Technology

ARL is pursuing research to provide enabling science and technology in propellants and propulsion for the FCS and Army Transformation. Insensitive High Energy Munitions (IHEM) research supports the development of propellants that will enable FCS armaments with increased muzzle kinetic energy, reduced vulnerability and acceptable mechanical properties. These propellants, when coupled with Electrothermal Chemical (ETC) propulsion concepts, offer the potential for significantly increasing the lethality of future weapon systems while improving overall platform survivability. In support of the joint ARL/ARDEC FCS Multi-Role Armament and Ammunition System (MRAAS) ATD, ARL performed critical vulnerability and ballistic characterization experiments, which led to the identification of several GEN II propellant formulations worthy of further consideration. In coordination with ARDEC, ARL demonstrated precision ignition and a 40% reduction in recoil forces using ETC and Fire-Out-of-Battery technology. ARL also worked closely with United Defense Limited Partnership to demonstrate that ETC injector technology is compatible with cased telescope cartridges. These combined efforts will lead to a joint ARL/ARDEC demonstration of a first generation MRAAS armament in FY2002.

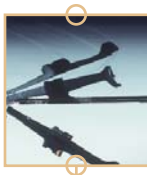
Multi-Disciplinary Design for Precision Munitions

Efforts to integrate aerodynamics, advanced structures, and guidance, navigation and control (GN&C) research are conducted to increase the probability of kill and reduce collateral damage for direct and indirect fire precision munitions. In FY2001, ARL coupled Computational Fluid Dynamics (CFD) code with Solid Dynamic algorithms and performed initial aerodynamic analysis of a "Smart Cargo" munition concept at anticipated flight conditions. In addition, CFD models of generic canard controlled planar and grid-finned flight bodies were completed and validated with wind tunnel data from the Defense Engineering and Research Agency (DERA), United Kingdom. Roll capability was also added to the code. Validated CFD models for advanced roll and maneuver control technology will continue to be evolved to enable development of future missiles and the "Smart Ammunition Suite" for the FCS Multi-Role Armament. In support of the joint ARL/AMRDEC MEMs-Based Angular Rate Sensor



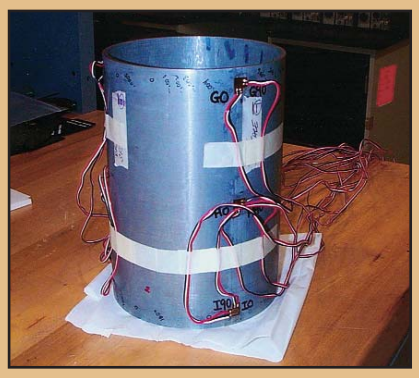
Computational Fluid Dynamics calculations of lattice tail fins.

LETHALITY



STO, ARL assembled a dual-axis angular rate sensor and experimentally validated what proved to be excellent performance over military environments (35K-g shock, -40 to 70 deg C). Efforts continue in collaboration with AMRDEC to evaluate novel packaging techniques to enable the use of this type of device in CKEM. These technologies will enable improved lethality and survivability for FCS and the Objective Force by increasing their effectiveness at long-standoff ranges.

Metal Matrix Composites for Ordnance Applications



Experimental characterization of Metal Matrix Composite specimen.

FCS and the Objective Force will require lightweight and more lethal projectiles and armaments to not only increase lethality, but to decrease the logistics burden. ARL is adapting continuous fiber metal matrix composite (MMC) technology from the commercial sector to enable a 50% weight reduction of future projectiles/gun barrels. As part of the MMC for Ordnance Applications STO, ARL completed an experimental characterization and analysis of 3M alumina fiber reinforced aluminum specimens which demonstrated excellent load-bearing properties required for lightweight projectiles (twice that of steel). Further experimental and analytical studies have shown promising joining designs for projectile applications. However, results of thermal loading studies have shown that this material may not be optimum for use in gun barrels. Thus ARL will focus continued efforts on development of these materials for lightweight cargo projectiles with greater payload capacity (electronics and/or sub-munitions) to enable required FCS and Objective Force munition lethality.

Electromagnetic Gun Technology

Electromagnetic (EM) armaments offer a potential leap-ahead capability for the Objective Force by improving lethality through hypervelocity launch, increasing survivability by eliminating propellants, and enhancing sustainment with higher stowed loads. The ARL is addressing EM technology challenges in a coupled basic and applied research effort. The Institute for Advanced Technology (IAT) at the University of Texas is executing a basic research program in hypervelocity physics and electrodynamics. During FY2001, IAT provided data establishing the hypervelocity performance of an important class of novel kinetic energy penetrators. They defined the physics associated with EM armature in-bore transition and made fundamental improvements to their experimental facility for the study of these processes. In addition, they developed advanced numerical models describing the EM weapons system and its interactions with the host platform. In the applied research area (EM Gun Technology STO), ARL constructed a program to overcome the technical barriers to developing an EM gun system. During FY2001, under an Other Transaction Agreement with Lockheed-Martin, a single pulsed power topology was selected and used to define an advanced objective system (FY2007 timeframe). With this as the baseline, specific technical challenges were identified and used to establish a proof-of-principle system (FY2004 timeframe). In addition to pulsed power, launcher and projectile designs were developed and prototypes built for evaluation in FY2002. ARL and its partners are making great progress toward developing robust EM gun technology that will provide revolutionary lethality for the Objective Force.


DATA
PAS DATA SIMULATOR

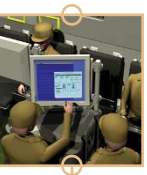
C⁴I

Provide future combat systems with technology for decision supremacy and enhanced survivability through decisive engagements

Leaders and soldiers need the capability to focus information for decision superiority and decisive engagement. Recognizing this, ARL is committed to accelerating and harnessing advances in information technologies. The Army must effectively integrate into its Command and Control (C^2) and weapons systems the spectacular advances in information sciences that enable gathering and distributing huge quantities of information at tremendous speed. ARL performs research that provides the fundamental scientific foundation necessary to exploit the technology of the Information Age. ARL's C^4I technologies will provide the Army with strategic, operational, and tactical information dominance across the entire spectrum of operations. Information technologies provide the Army with two distinct advantages. The first is a shared real-time situational awareness among all friendly elements to give commanders the unprecedented ability to develop operational plans, implement the plans in a simulated environment, and make revisions to the plans before executing the plans against enemy forces. The second advantage is real-time force synchronization which effectively multiplies the combat power brought to bear on the enemy.

Battlefield Information Processing

This research effort focuses on significantly improving the information access and operator focus of attention so that significant battlefield events are rapidly perceived and readily understood by commanders and staff with minimal interaction. The control of sensor suites and visualization of the



sensor information could overload communication pipes and people who must assimilate the information.

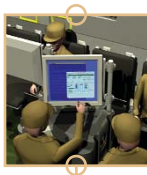
FY2001 accomplishments:

- Successfully investigated, designed, implemented and demonstrated a service-based processing infrastructure for planning and control of distributed manned and autonomous platforms. This software infrastructure technology will enable the Army to easily build software systems that are extensible across multiple battlefield functional areas.
- Developed a suite of client applications and services that integrates an in-house robot testbed with speech modality.
- Conducted a preliminary investigation into using XML as the underlying representation for abstracting and exchanging operational planning information. The results indicate that even though XML provides a rich form for describing information, this robustness is obtained at the cost of increasing the size of the information to be exchanged.
- Collaborated with PM Soldier to investigate extending the Land Warrior system to use sensing on robotic platforms. Suites of very thin client applications were developed to run on the Land Warrior system. Through these clients the Land Warrior system was able to task a robot, have the robot send its GPS location and heading under user-specified conditions, and utilize the processing power on the robot to perform sensor information processing, e.g. acoustic detection and low level image processing.
- Collaborated with the University of Maryland in using agent-based technology in conjunction with 2-D and 3-D visualization to monitor key events on the battlefield.

Information architecture to conduct operations in a widely distributed battlespace environment.

Determination of Atmospheric Propagation and Aerosol Impacts to Battlefield Operations

The Army of today and the future is required to operate and engage the enemy in the surface boundary layer of the atmosphere where acoustic and electro-optic propagation are most susceptible to degradation and interference by highly variable weather impacts, such as turbulence and precipitation. In addition, the presence of aerosols, both natural and man-made, in this atmosphere can have profound effects on the environmental conditions that can either hamper or assist military operations. The development and evaluation of various forms of propagation models that incorporate the environmental effects of the atmosphere in relation to turbulence, terrain, forests, urban structures, and land-water interfaces will be necessary to determine proper sensor deployment and ensure optimum performance, as well as improve the ability to accurately depict these effects in simulations for training and mission rehearsal. Additionally, the development of strategies and methods for obtaining and assessing information regarding the presence, type, and dispersion of chemical and biological aerosols in the environment will enable the Objective Force to rapidly characterize these threats and improve the survivability and effectiveness of the soldier.



FY2001 accomplishments:

- A prototype Fluorescence Particle Spectrometer (FPS) was constructed that has sufficiently high sample rate to measure fluorescence spectra of aerosols in ambient air. The FPS incorporates a virtual impactor and an aerodynamic focusing nozzle in its inlet that provides for concentrating 1-10 micrometer particles by a factor of several thousand, enabling the FPS to sample air at useful rates (several liters/minute). A prototype diode-pumped laser-based FPS (with 32 channel fluorescence spectra capability) was delivered to USAMRIID for use in their bio-agent class-III hoodline.

Collaborative Technology

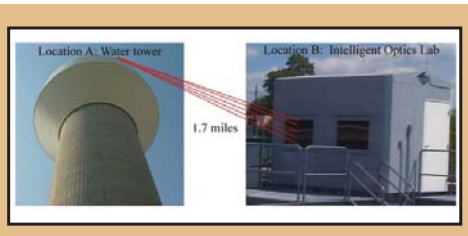
Goal: Enable the warfighter to operate within the enemy's decision cycle.

The objective of this effort is to develop and prototype a set of collaborative planning tools to focus on compressing the Observe-Orient-Decide-Act (OODA) loop and provide commanders and staff with the capabilities to plan and execute within the enemy's decision cycle. FY2001 results were demonstrated at the Federated Laboratory Symposium, and the Group Systems effort played an integral part in the Prairie Warrior 01 exercise at Fort Leavenworth, Kansas. (Integrated touch-sensitive smart board with map displays with input capture systems for easier usability by military commanders and operators.) Also integrated were speech-based query of databases for situational awareness information on objects on the smart board map. Ongoing FY2002 efforts are focused on developing an intelligent agent architecture in conjunction with a central data warehouse to provide maximum visualization without information overload.

Free Space Optical Communications

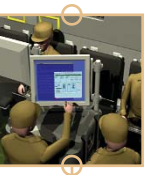
This research is focused on developing algorithms, techniques, and devices for advanced military communication, imaging, and image processing systems. FY2001 accomplishments include:

- Demonstrated integrated MEMS/VLSI system for adaptive phase distortion correction using parallel stochastic gradient descent technique;
- Demonstrated a high-resolution and fast wavefront sensor (300 f/sec frame rate, 8 micron resolution, 512x512 image resolution, 0.5 nW/cm2 sensor sensitivity);
- Demonstrated an adaptive system for eye retina imaging based on model-free optimization technique.



Atmospheric Laser Optics Testbed to evaluate products under actual atmospheric conditions.

The advantage of Wavefront control is that it requires neither a reference wave nor direct wavefront measurements. Initial development of new facilities for experiments in the area of laser communication, laser designation and imaging called, "Atmospheric Laser Optics Testbed (A-LOT)" included design and layout of the systems and components, sizing and specification of components and equipment, and system acquisition. Assembly is underway.



Multi-Lingual Tools for HUMIN/CI ACTD

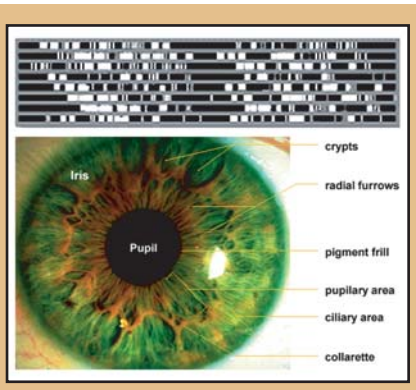
Research focus is on development of computational multi-lingual tools to support tactical, intelligence, special forces (SOF), military police, and coalition operations, so that the Objective Force can communicate with allies and anticipate the actions of adversaries.

FY2001 accomplishments:

- European (Russian, Serbo-Croatian, French) Forward Area Language Converter (Falcon) transitioned to PM Intel Fusion for fielding to 120 Counter Intel, Human Intel, Automated Tools Set (CHATS) units. Also transitioned this Falcon to IBDE (Interim Brigade), Fort Lewis, Washington.
- A Technology Planning Annex (TPA) is in place with CECOM C2 and CECOM CINC Interoperability Program Office -CIPO. CECOM coordination extends from European Falcon to Korean and Arabic. Facilitating CECOM transition is CIPO CECOM, which alerted CINCs about Falcon capabilities on behalf of CECOM in September 2001.
- Asian Falcon transitioned to USARPAC in May 2001. Arabic Optical Character Recognition and Machine Translation (MT) originally evaluated under DARPA and Translingual Information Decision Extraction and Summarization (TIDES) program are now incorporated into Falcon. Additional Natural Language Processing (NLP) TIDES research is under active consideration for inclusion into Falcon beginning with Korean language. New Falcon integration was evaluated at ARL and in two field exercises: Bold Knight (Fort Gordon, Georgia, June 2001) and Intrepid Knight (Fort Gordon, Georgia, August 2001).
- Tested Translingual Information Retrieval ontology, named RAVEN, and extended to Korean with fuzzy math weightings.
- Constructed evaluation suites for embedded MT evaluation covering Arabic, Spanish, and Haitian Creole.
- Developed measures of performance applied across languages. Extended NLP interfaces, integrated with gestural inputs, to work with the basic commands required to control physical agents (robots).

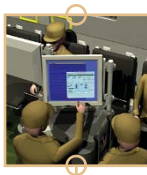
Allows users with no foreign language training to convert a foreign language document into an approximate English translation.

Personal Identification Pilot



Iris imaging and face recognition.

This research demonstrated a medium-scale visitor tracking capability using biometrics for the Deputy Under Secretary of Defense (DUSD) Science & Technology (S&T), integrating commercial-off-the-shelf (COTS) iris scanning and face recognition systems with e-commerce solutions. The research plan contained requirements to evaluate in a statistically meaningful way the performance of the system including enrollment time, identification time, error-rate, and false-positive rate. ARL completed a six-month Phase 1 iris recognition data collection effort in April 2001. In June 2001, ARL delivered to DUSD (S&T) a preliminary assessment report incorporating the Phase 1 performance and provided recommendations concerning the merits of iris recognition in visitor



control. ARL then added a second phase to evaluate face recognition technologies. Phase 2 data collection started in July 2001 and the final report includes assessments of both iris and face recognition technologies as well as recommendations for fielding these technologies in visitor control applications.

Smart Sensor Communication Network

The focus of this program is to develop breadboard radio design including hardware and networking software. The initial radio design must demonstrate a low-energy receiver with low-probability detection/antijam (LPD/AJ) characteristics. The initial design will not be miniaturized. However, reduction in size and cost will be built into later editions. The networking software will demonstrate Ad-Hoc Networking for a small number of nodes.

FY2001 accomplishments:

- A preliminary breadboard radio design was completed that included low-energy receive operation.
- Breadboard hardware has been built and tested.
- Ad-Hoc Networking software has been developed and refined to do distributed computation of routing tables. Additionally, a migration path making it feasible to commercially produce this board has been identified. This allows for rapid integration into unattended ground sensor products. DARPA MiUGS sensor program has selected this technology and migrated the product as their first choice for their communications needs. Deliverables: (1) Control software has been implemented in Linux with the additional feature of distributed computation of routing. Initial porting of software to M-core has taken place, and this work is continuing. (2) The digital signal processing section has been designed and tested. (3) The brassboard RF design section has been completed and tested.


silicon graphics octane
sgi
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SENSORS

Provide the warfighter innovative sensor and electronics technology for enhanced situational awareness, precision strike, and mobility

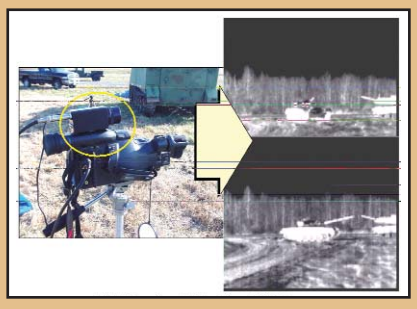
Innovative sensor technology research is performed by ARL to achieve the maximum impact on future Army and DoD systems. Included in this research are electro-optical, microwave, RF and acoustic sensors, and physical sciences and technology for electronic, photonic and micro-electro-mechanical devices, power sources, non-lethal and directed energy weapons, and protection against lasers and electromagnetic environment effects.

Networked Microsensors

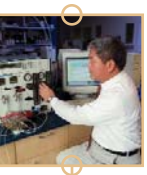
The objective is to develop the supporting technologies that will lead to small, networked, low-cost battlefield sensors that can passively detect, locate, track and identify personnel, ground vehicles, aircraft, artillery, mortars, and other battlefield targets. The advanced sensor and communication technologies will provide low-cost, high-payoff performance to enhance the performance of individual soldiers and munitions. This program directly supports the Army Vision and the FCS requirements of extended range engagement and assessment, positional advantage, lethality and survivability by providing the Army with revolutionary situational awareness across all echelons of the battlefield.

FY2001 accomplishments:

- Prototype hardware for the Basic Orthogonal Sensor System (BOSS) has been completed and tested in the laboratory.



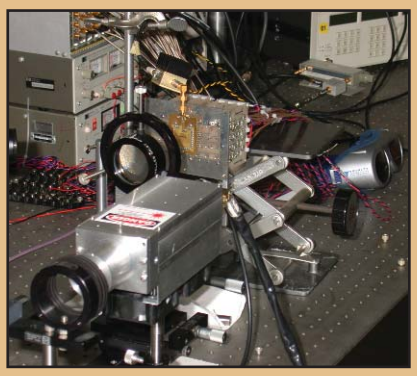
Field Experiment Data Using UL3 IR Camera.



- Acoustic/seismic/day camera/UL3 IR micro camera sensor testbed prototype hardware was completed and demonstrated at the FY2001 Federated Laboratory Symposium.
- During a field experiment held on Spesutie Island, Aberdeen Proving Ground, Maryland, during December 2000, computing Architecture for Micro Sensors (CAuS) hardware was demonstrated executing ARL acoustic algorithms.
- Initial fabrication completed on constituents for spin dependent tunneling sensors in support of WEBS APLA programs. Transition to CECOM for use in FCS will occur after additional development and testing.

Line Array Ladar

This research focus is on demonstrating a major advance in ARL ladar technology by designing and building a 32-pixel line scanning ladar with significant performance improvements and enhanced capability for data collection. The potential exists to provide small, low-cost ladar systems for smart munitions, foliage penetration, armor protection, robotic visualization, and other applications. This will result in one to two orders of magnitude higher data rates or an order of magnitude greater range capability.



1 x 32 Line Array Ladar Brassboard.

FY2001 accomplishments:

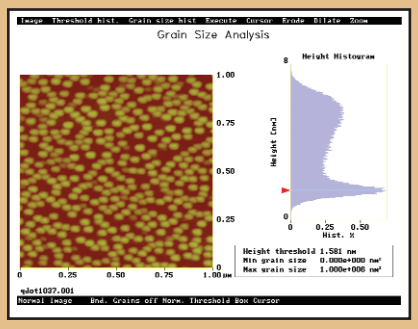
- The 32-pixel line-scanning instrument-quality ladar breadboard was completed and operated in the laboratory. The 1x32 GaAs metal semiconductor metal detector/mixer array has excellent performance, as have all the other receiver components, as well as the 3.3-W transmitter, the wideband chirp generator, and the 32-channel data acquisition system. Some recently added design features to enhance control of the ladar for data acquisition are now being completed prior to brassboard integration and final packaging.

Low Frequency Modeling of Tactical Vehicles

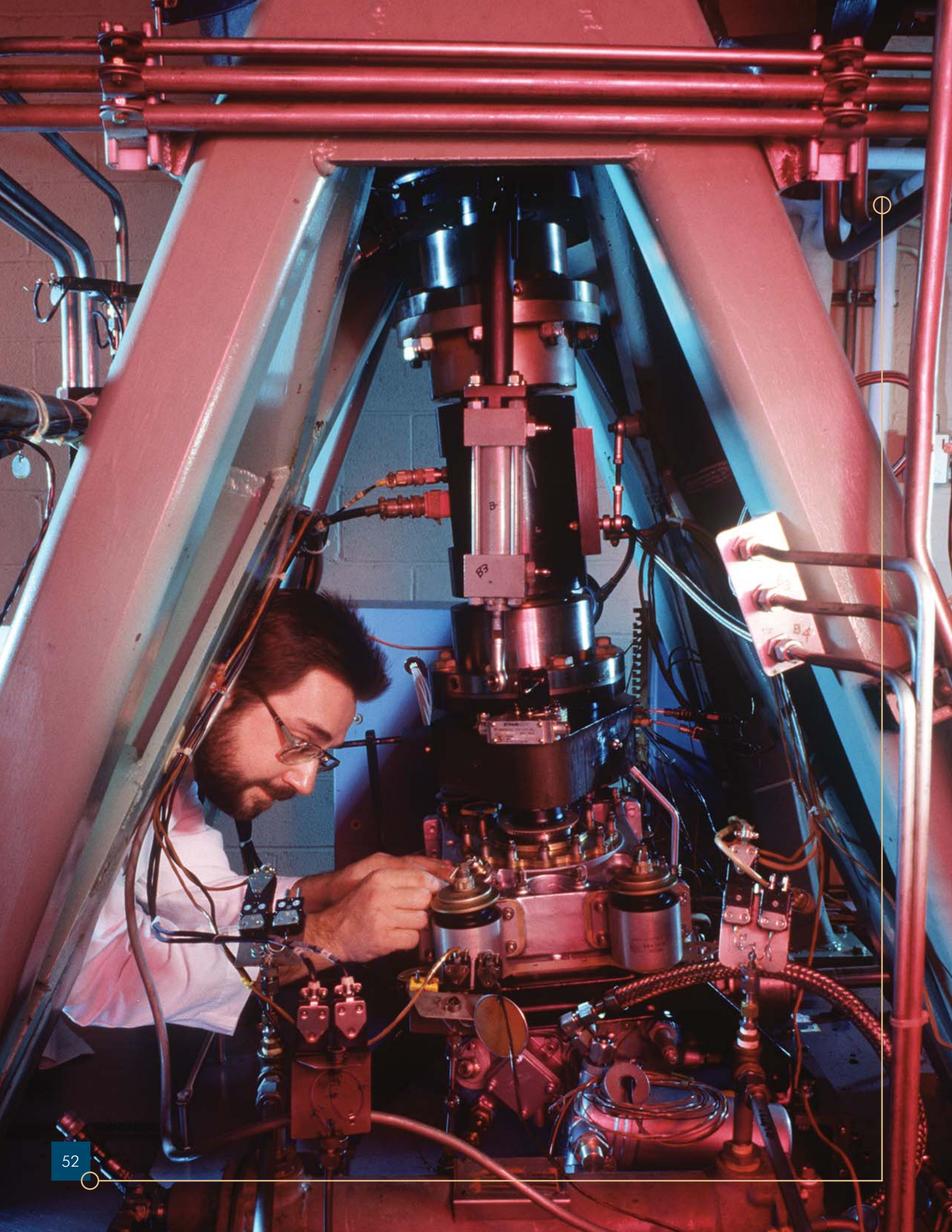
ARL computed backscatter over the VHF band for a T-72 (at two different depression angles), M1, and for a generic tree model. ARL validated the code by modeling an eight-foot trihedral and comparing the model to measurement data provided by the Boom Synthetic Aperture Radar (SAR) from the Yuma, Arizona, field test. A linear superposition technique was developed to combine the responses from many trees and the tank model to produce SAR images of tactical vehicles in a forested area. From a radar point of view, this is important because modeling the clutter is as important as modeling the target itself. This forest model is the first of its kind. Combined with this algorithm was an extension of the parallel method of moments developed for High Performance Computing. This can be considered a computational breakthrough as the RAM and CPU bottleneck was relieved (or at least pushed back) though parallelization.

Self-Assembled Quantum Dots for IR Detection

Quantum Well Infrared Photodetectors (QWIP) have attractive properties but are not sensitive to radiation incident normal to the chip surface. Quantum Dot Infrared Photodetectors (QDIP) may provide similar performance benefits without the need for devices to couple the radiation to the surface. Temperature dependent measurements on quantum dot detector samples were used to design new barrier layers in detectors to improve detectivity and increase operating temperature. The basic theoretical model was refined, including oblate spheroidal coordinates, and used to describe observed infrared transitions in quantum dot samples. Molecular beam epitaxy was used to grow single quantum dot layers using InAs and InSb on GaAs, InP and InAs substrates. Multiple layers of doped quantum dots were grown between doped contact layers to form a QDIP. Layers were characterized using x-ray diffraction, atomic force microscopy and transmission microscopy. QDIP's were shown to respond to all polarizations of light in the 3-12 micron wavelength region and, therefore, can be used as normal incidence detectors without the need for optical coupling structures required for QWIP's. Continued effort focuses on improving the detector several orders of magnitude with plans to transition to CECOM.



Atomic Force Micrograph of Self-Assembled InAs Quantum Dots.


B3
B4

SUSTAINABILITY

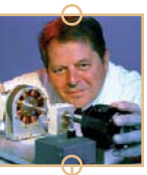
Innovative technologies to enable responsive mobility and sustainability at strategic, operational, and tactical levels

The ability of the Army to project and sustain combat-effective forces on a global basis is strongly dependent on certain attributes of the air and ground vehicles that make up the force structure. Transportability depends on the vehicle size and weight, and in the case of air vehicles, self-deployability is highly desirable. Force sustainability is heavily influenced by platform fuel demands, spare parts requirements, and the resupply of consumable items (lubricants, track pads, filter media, etc.). The challenge will be to provide a technology base to enable the future development of small, easily sustainable, lightweight, and durable platforms that can meet all projected future combat capability demands.

ARL's research and technology thrust areas include: more powerful, lightweight, fuel efficient propulsion systems; advanced, lightweight, high-strength composite materials; analytical capabilities in structural mechanics and dynamics to enable platform systems optimization; and fully integrated engineering design tools that will allow the simultaneous design of mission, weapons, and crew system packages into the platform.

Reliability-Based Structural Design

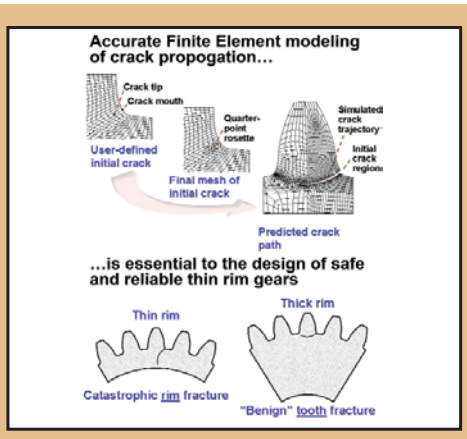
The Army's Objective Force must be more deployable, more agile, smaller in logistics footprint, more lethal, survivable, and more tactically mobile. The challenge for future Army vehicles is to achieve higher reliability and durability so that structures will rarely, if ever, fail before reaching their



expected retirement lives. The benefits of increased reliability and durability are improved safety, reduced maintenance costs, and improved readiness. Historically, reliability and durability improvements incur a trade-off in terms of increased weight and higher production costs, but ARL Vehicle Technology Directorate researchers, working in conjunction with their NASA counterparts, are changing this paradigm by developing and applying novel possibilistic and non-deterministic methods to more accurately assess reliability-based design approaches. In FY2001, Army/NASA researchers analyzed the reliability of a cracked-lap shear specimen, which closely simulates a joint common in many airframe structures, to evaluate the probability and possibility of failure. The results indicate that the new analytical techniques will allow a ten-fold reduction in fatigue testing and that they will be useful in the study of uncertainty during the critical early stages of design. Other new design methods were developed that incorporated probabilistic tools with design optimization. These included reliability as a design constraint and showed that the new, more computationally intensive, reliability-based design methods do have the potential to eliminate the conservative design barriers that currently preclude lighter, more durable, and highly reliable Army vehicles for the Objective Force. The results were communicated to industry and academia through various American Helicopter Society sponsored technical conferences and at Rotorcraft Center of Excellence forums.

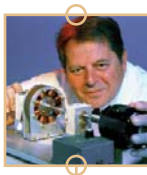
Thin Rim Gear Design Guidelines

Weight reduction is a prominent concern for aircraft; aircraft designers have struggled to keep aircraft weight low while maintaining robust durability and reliability. This demand for reduced weight subjects the gears in rotorcraft transmissions and drivetrains to very severe loading conditions that are far above those of typical ground vehicle transmissions. The intense loading is a direct consequence of reduced drivetrain weight which has increased the concern over possible major structural failures in rotorcraft drivetrains. A crack that initiates at a gear tooth root might propagate through the rim, resulting in massive failure and a catastrophic accident.



Active Twist Rotor Concept for Rotorcraft Vibration Control

Excessive helicopter fuselage vibration is a major contributor to pilot fatigue and high aircraft maintenance costs. The Army's Objective Force requires helicopters with improved performance and significantly reduced maintenance burden. Helicopter rotor individual blade control promises to provide a mechanism to reduce vibration levels, improve rotor performance, reduce vehicle noise, and reduce maintenance requirements. Active materials can accomplish individual blade control through strain-induced rotor blade twisting using piezoelectric active fiber composite actuators embedded in the blade structure. To validate this idea, researchers from ARL's Vehicle Technology Directorate teamed with NASA to design and fabricate a four-bladed, aeroelastically-scaled, Active Twist Rotor (ATR) model. This model was tested in the Langley Transonic Dynamics Tunnel, representing the first time that an integral twist rotor blade has been demonstrated in forward flight. ARL engineers analyzed the data in FY2001 and the results showed an excellent potential for vibration control. VTD presented the summarized findings to the American Helicopter Society's Annual



Forum in May 2001. A more comprehensive set of analysis, hardware details, and information about the test set up were also transitioned to the three major American helicopter companies. In addition, VTD made further improvements to the piezoelectric active fiber composite technology, which extended the twist range capability.

Centrifugal Compressor Flow Range Extension

Future rotorcraft and future unmanned aerial vehicles for the Army's Objective Force will require small turbine engines with increased levels of performance. The performance of small gas turbines has been driven to higher levels under Phase III of the Integrated High Performance Turbine Engine Technology (IHPTET) program, but greater loading on the engine compressor stage has increased the difficulty of sustaining stable engine operation over a broad power range. During FY2001, ARL researchers collaborated with NASA, the Air Force, the Navy, universities and industry to develop methods for increasing the stable flow range of small turbine engine compression systems. The researchers employed a novel technique that involved the injection of air through key surfaces in the compressor space. The results demonstrated a major flow range extension of more than 20% using less than 1% of the total compressor airflow. The knowledge gained in locating, orienting, and sizing the new compressor flow injectors has established a firm foundation for future engine performance and stability investigations. In FY2002, experiments will be conducted to evaluate the promising area of recirculating air injection and to prepare for the eventual demonstration of this technique in an actual Army aircraft engine. Test results affirm the potential of this approach as an effective enabler for very high performance small turbine engines.

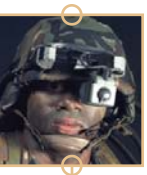
HUMAN DIMENSION

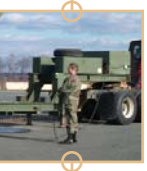
Maximize soldier performance in Army systems

The key to Army success is the enhancement of soldier operating performance, proficiency, adaptability, and confidence. ARL is an eminent player in human factors technologies. ARL's program supports future joint warfighting capabilities, from engaging regional forces on a global basis to operations other than war. Fewer soldiers using more complex systems brings a greater potential for sensory and information overload. Increased tempo from 24-hour operations and shortened decision times contribute to an urgent and continuing need for the Army to increase the performance of individual soldiers, crews, units, and staffs under conditions of hostility and high stress. To maintain world leadership in human factors and MANPRINT, ARL is emphasizing, exploiting, and expanding the understanding of soldier perception and cognition, individual and team decision-making under stress, crew performance in complex task environments, and numerous other problem areas unique to the Army operational environment.

The Effect of Spatial Audio Displays and Automatic Speech Recognition on Soldier Performance in Ground Combat Vehicles

When soldiers must perform complex concurrent tasks in the presence of environmental noise, results have indicated that advanced technologies such as Automatic Speech Recognition (ASR) and spatial audio displays could be integrated together as useful real-life applications in future crew systems. The data indicated no discernible integration issues concerning





audio display input and speech recognition output utilized in the same crew system. An auditory display type can enhance the ability of the user to process radio communications. In the extremely difficult radio monitoring conditions in this study (monitoring two to four radio channels with simultaneous incoming messages, in very loud background noise), subjects showed a 48% improvement in identifying target radio messages with 3-D audio over existing monaural communication systems. ASR performance data indicated that 98% of all subject commands were recognized by the ASR. Of the command sentences not recognized, the largest percentage of errors (34%) were caused by user pauses when uttering commands, which resulted in the ASR not recognizing the command as a distinct phrase.

MANPRINT Support to Crew Integration of the Comanche

ARL provided the Program Executive Officer - Aviation with MANPRINT and Human Factors Engineering Support for the effective integration of aviation crews in the Comanche helicopter. During FY2001, ARL conducted a series of anthropometric evaluations utilizing Human Figure Modeling to optimize the Comanche crew station design. These evaluations resulted in a series of recommended changes to seat adjusters, consoles, pedals and the collective. When implemented, they will result in the ability to accommodate 40% more soldiers in the cockpit, increased usability and comfort, and reduced fatigue. Additional evaluations (originally planned for FY2001) will be conducted in 2002 on a Comanche mock-up to address crew emergency ingress and egress. ARL will also conduct workload and crew station integration evaluations during force development test and evaluations to determine if the crew station design maximizes total soldier system performance and will provide recommendations to alleviate any identified shortfalls.

ANALYSIS



Survivability and lethality of our systems and soldiers are critical to our success as a nation. ARL is the only Army source for fully integrated survivability and lethality analyses spanning all threats. Such analyses are required by Department of Defense regulations.

ARL provides basic and applied research data that enables the Department of the Army decision makers and program managers to approve the acquisition of survivable and effective systems for the Army of the future.

ANALYSIS

Air and Missile Defense: THAAD IR Countermeasures Scene Generation, Phase 1

The first phase of infrared (IR) scene generation, as it applies to Theater High Altitude Air Defense (THAAD), encompasses the understanding of THAAD-related simulation used for analysis of the terminal phase of the interceptor. ARL developed realistic trajectory models for targets and missile using available THAAD field data and threat trajectory data. Because the field data used was from the radar system itself and was influenced by the operational objectives of the radar, ARL analysts were required to smooth the data in order to properly orient the trajectory relative to the intercept missile and any countermeasures which the missile intends to deploy.

ARL developed multiple target trajectories for use in IR scene generation of infrared countermeasures (IRCMs). They based the trajectories on test data from live firings and used the previously developed smoothing techniques. After confirming that they had correctly modeled the physics, ARL scientists and engineers developed scenes using field measurements, when available, and IR databases. They developed both benign scenes, to demonstrate threat signatures, and intercept scenes. They verified these simulations against field data, when available, and against physics definitions of threat and intercept performance when necessary. Finally, they developed countermeasure conceptual designs. Evaluation of scene generation methods and support tools for using field data is now complete and ARL has begun making runs for record. Analysts are integrating scene data for processing by the THAAD sensor model.

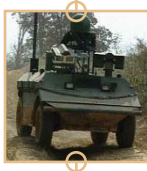
Aviation Systems: Tactical UAV (TUAV) MSIII Evaluation Support

ARL has been providing significant analysis and measurement support for the TUAV MSIII decision, originally scheduled to be conducted in September 2001, and now planned for September 2002. At the request of the Army Test and Evaluation Command (ATEC), Army Materiel Systems Analysis Activity (AMSAA) and the TUAV Program Management Office (PMO), ARL was asked to measure and analyze the aircraft's dynamic infrared signature as well as the acoustic and visible signatures during operational testing. When completed, ARL will also provide these data to AMSAA for use in their threat survivability models.

ARL completed an Information Operations Vulnerability/Survivability Assessment (IOVSA), Phase 1 (system familiarization) for the TUAV. The objective of an IOVSA is to answer questions: Does the platform have any IO susceptibilities and/or vulnerabilities to be concerned about? If so, what needs to be done to protect the platform from the IO threat? System familiarization is one of five phases of an IOVSA. The other phases include Systems Design Analysis, Threat Definition and Susceptibility Assessment, Vulnerability Risk Assessment, and Protection Assessment and Recommendations. The System familiarization phase includes the external environment (e.g., data input to the system) and the system being assessed (e.g., hardware and system applications). ARL documented these efforts in a technical report provided to the PMO. Planned efforts for MANPRINT assessment, E3 measurements, and E3 evaluation plan review have moved to FY2002 due to program slippages. ARL completed partial analysis of the Block I data link but Block II information has not been finalized.

C^{4}I/IEW: Information Operations Vulnerability and Survivability Analyses

In FY2001, the Director of Information Systems for Command, Control, Communications & Computers (DISC4) tasked ARL to perform Information Operations Vulnerability Survivability Analyses (IOVSAs) on 14 of the top 15 First Digitized Division (FDD) priority list to identify vulnerabilities and determine possible mitigation techniques. Associated with that task was the requirement to populate the ARL's Security Tools, Exploits, and Vulnerability Database (STEVdB) with the resultant information for access by PMs, DA staff, and unit commanders through appropriate chains of command, and also to develop methodology to analyze results of various FBCB2 field tests prior to MS III. ARL identified more than 200 recommendations for improvements to survivability. Results of IOVSAs were cited as examples of Army readiness by DISC4 to Congressional inquiries. ARL entered information from IOVSAs into STEVdB as analyses were completed to ensure that the most current information would be available for the controlled dissemination of vulnerabilities and corrective actions to the materiel development community in order that they may profit from ARL's experience. The STEVdB server was connected to SIPRNET to allow access. ARL also developed and is using this methodology to analyze the results of recently completed Force XXI Battle Command Brigade and Below (FBCB2) FT4. The Army Information Operations (IO) Council of Colonels recommended that STEVdB be made part of the Army IO Campaign Plan for continuing DISC4 funding throughout FY2003-2007 POM.



Ground Systems: Survivability Analysis for the Interim Armored Vehicle

The Interim Brigade Combat Team (BCT) is designed to optimize its organizational effectiveness and seeks to balance the traditional domains of lethality, mobility, and survivability with the domains required for responsiveness, deployability, sustainability, and reduced in-theater footprint. In FY2001, ARL served as a member of the Medium Armored Vehicle (MAV) Comparative Evaluation (CE) Senior Advisory Group, the Interim Armored Vehicle (IAV) Live Fire Working Group, the Test and Evaluation Integrated Process Team (IPT), and the MANPRINT Domain IPT (soldier survivability), providing inputs to the Live Fire Strategy, the Test and Evaluation Master Plan (TEMP), the System Evaluation Plan (SEP), and the Simulation Support Plan. To support the MAV CE and IAV LFTE program schedules, and in support of the Congressionally mandated comparative analysis between the IAV and a M113 equipped force, ARL constructed the necessary target descriptions and the associated criticality analyses and other related inputs required for ballistic vulnerability and preshot modeling and simulation. ARL has continued to participate in the test and evaluation, modeling and simulation, live fire, and non-ballistic survivability IPTs to discuss and plan future program tests, experimentation, modeling and simulation, analysis of system vulnerability, information assurance, and soldier survivability. ARL prepared the Behind-Armor-Debris (BAD) experimental plan, and experiments began in October 2001. Shot Line draws have been tentatively scheduled by ATEC, and ARL will be supporting these draws using the ICV 3-D geometry. The Live Fire IPT approved ARL's approach. Using the 3D geometry to determine LFTE shotlines will save time, improve accuracy, and help identify shot line issues/concerns well before the start of Live Fire testing in April 2002. ARL worked closely with PM BCT and ATEC to optimize the use of armor coupons for data collection, thereby minimizing costs to PM BCT. Although several efforts, including model input development and pre-shot predictions, were delayed due to the program shutdown caused by the General Accounting Office contract protest, ARL has worked diligently to ensure that preshot predictions will be available on schedule for the start of IAV Live Fire testing in April 2002.

Munitions: Tank Extended Range Munition (TERM) CFT Support

TERM is a PM-TMAS (Tank and Medium-Caliber Armament Systems) program undergoing system integration. TERM is intended to be a new smart 120-mm tank round to be fired from the Abrams main battle tank to engage threat targets beyond the line-of-sight, either in (laser) designated or (infrared and/or millimeter wave) autonomous modes out to 10 kilometers. During FY2001, ARL provided electronic warfare analysis/support for two captive flight tests (CFT) conducted at Redstone Technical Test Center in Huntsville, Alabama. ARL's support included threat countermeasure emplacement, collection of high-resolution target signature and ground truth data for applicable infrared and millimeter wave (MMW) wavebands. Following completion of the field investigations, ARL analyzed the high-resolution data as applicable to target detection by the actual sensors, and calculated expected probabilities of detection.

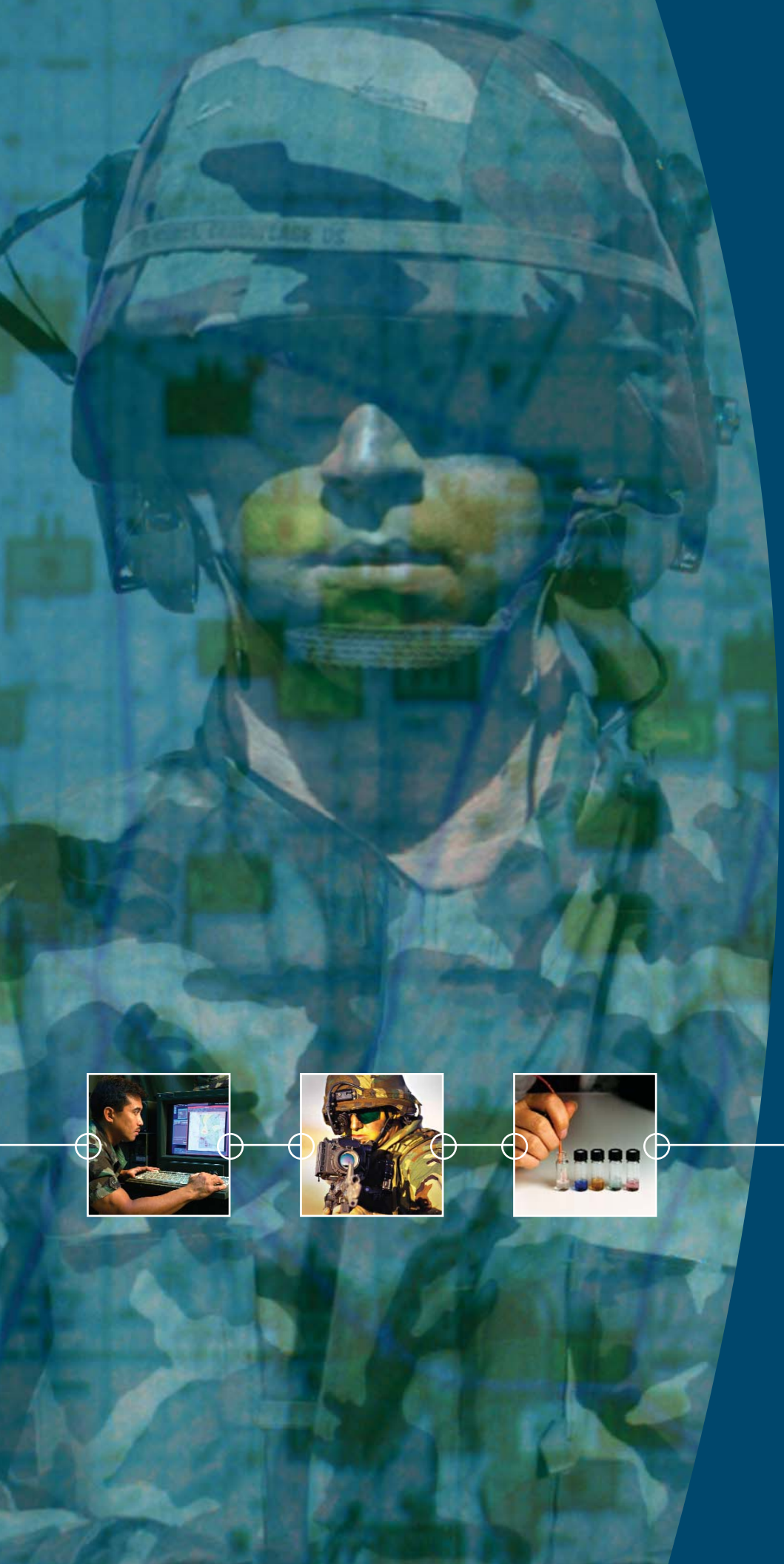
GLOSSARY

AGL	Above Ground Level
ATD	Advanced Technology Demonstrations
A-LOT	Atmospheric Laser Optics Testbed
AMSAA	Amy Materiel Systems Analysis Activity
ARL	Army Research Laboratory
AMRDEC	Aviation & Missile Research, Development, & Engineering Center
ARO	Army Research Office
ASR	Automatic Speech Recognition
ATEC	Army Test and Evaluation Command
ATR	Active Twist Rotor
AWG	Arrayed Waveguide Gratings
BAD	Behind-Armor-Debris
BCT	Brigade Combat Team
BOSS	Basic Orthogonal Sensor System
C2	Command and Control
C^4I	Command, Control, Communications, Computers and Intelligence
CAuS	Computing Architecture for Micro Sensors
CCD	Change Coupled Device
CE	Comparative Evaluation
CECOM	Communications and Electronics Command
CFD	Computational Fluid Dynamics
CFT	Captive Flight Tests
CISD	Computational and Information Sciences Directorate
CKEM	Chemical Kinetic Energy Missle
CMOS	Complementary Metal Oxide Semiconductor
COTS	Commercial-off-the-shelf
CSA	Chief of Staff, US Army
CTAs	Collaborative Technology Alliances
DA	Department of the Army
DARPA	Defense Advanced Research Project Agency
DERA	Defense Engineering and Research Agency
DISC4	Director of Information Systems for Command, Control, Communications & Computers
DoD	Department of Defense
DUSD(S&T)	Deputy Under Secretary of Defense (Science & Technology)
EM	Electromagnetic
ETC	Electrothernam Chemical
FAP	Fluoroalkyl phosphorous
FBCB2	Force XXI Battle Command Brigade & Below
FCS	Future Combat Systems
FDD	First Digitized Division
FPS	Fluorescence Particle Spectrometer (FPS)
GEN	Generation
GN&C	Guidance, Navigation and Control
HMMWV	High Mobility Multipurpose Wheeled Vehicle
HRED	Human Research and Engineering Directorate
HUMIN/ CI ACTD	Human Intelligence/Counter Intelligence Advanced Concept Technology Demonstration
IAT	Institute for Advanced Technology
IAV	Interim Armored Vehicle
IHEM	Insensitive High Energy Munitions
IHPTET	Integrated High Performance Turbine Engine Technology
IO	Information Operations
IOVSA	Information Operations Vulnerability Survivability Analyses
IPT	Test and Evaluation Integrated Process Team
IR	Infrared
IRCMs	Infrared Countermeasures
KE	Kinetic Energy
LFTE	Live Fire Test and Evaluation
LOSAT	Line of Sight Antitank
LPD/AJ	Low Probability Detection/Antijam
MANPRINT	Manpower and Personnel Integration
MAV	Medium Armored Vehicle
MEMS/VLSI	Micro Electro Mechanical Systems/Very Large Scale Integrated Circuitry
MMC	Metal Matrix Composite
MRAAS	Multi-Role Armament & Ammunition System
OODA	Observe-Orient-Decide-Act
PLIF	Planar Laser-Induced Fluorescence
PM Soldier	Program Manager Soldier
PMO	Program Management Office
QDIP	Quantum Dot Infrared Photodetectors
QWIP	Quantum Well Infrared Photodetectors
RDEC	Research, Development, and Engineering Centers
RF	Radio Frequency
RPG	Rocket Propelled Grenade
SAR	Synthetic Aperture Radar
SBCCOM	Soldier, Biological, and Chemical Command
SEDD	Sensors and Electron Devices Directorate
SEP	System Evaluation Plan
SIPRNET	Secret Internet Protocol Network
SLAD	Survivability and Lethality Analysis Directorate
SOF	Special Forces
STARS	Science and Technology Academic Recognition System
STEVdB	Security Tools, Exploits, and Vulnerability Database
STO	Science and Technology Objective
TACOM	Tank Automotive Command
TARDEC	Tank Automotive Research, Development & Engineering Center
TEMP	Test and Evaluation Master Plan
TERM	Tank Extended Range Munition
THAAD	Theater High Altitude Air Defense
TIDES	Translingual Information Decision Extraction and Summarization
TMAS	Tank and Medium-Caliber Armament Systems
TPA	Technology Planning Annex
TRL	Technology Readiness Level
TUAV	Tactical Unmanned Aerial Vehicle
UGV	Unmanned Ground Vehicle
USAMRIID	US Army Medical Research Institute of Infectious Diseases
USARPAC	US Army Pacific
VTD	Vehicle Technology Directorate
WEBS APLA	Warrior Extended Battlespace Sensors Anti Personnel Land Mine Alternatives
WMRD	Weapons and Materials Research Directorate
WSR	Weather Surveillance Radar-1988 Doppler

The U.S. Army Research Laboratory
is a major subordinate command of
the U.S. Army Materiel Command

U.S. Army Research Laboratory
2800 Powder Mill Road
Adelphi, MD 20783-1197

Toll free: 1-877-ARMY-LAB
www.arl.army.mil



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